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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 166.

A. C. TRUE, Director.

COURSE IN CHEESE MAKING

FOR

MOVABLE SCHOOLS OF AGRICULTURE.

BY

L. L. VAN SLYKE, Ph. D.,

Chemist, New York State Agricultural Experiment Station.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1906.

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U. S. DEPARTMENT OF AGRICULTURE.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., February 5, 1906.

SIR: I have the honor to submit and to recommend for publication as Bulletin 166 of this Office, a Course of Instruction in Cheese Making for Movable Schools of Agriculture, prepared by L. L. Van Slyke, chemist of the New York State Agricultural Experiment Station. The intent of the projected series of courses of which this is the first is, as explained by the Farmers' Institute Specialist of this Office, to give more extended and specific instruction in agriculture outside of regularly organized schools than is now being given in the farmers' institutes of the country. The value of such instruction has been clearly demonstrated in many foreign countries and there seems to be a real and growing need for it in the United States, especially in those States where farmers' institutes have been longest in operation.

The subject of cheese making has been reduced to relatively satisfactory pedagogical form, and it is therefore hoped that the course herewith submitted will serve to indicate what may be done in the preparation of similar courses in other subjects, many of which will doubtless have a wider application in this kind of instruction.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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PREFATORY NOTE.

This course of instruction in cheese making by L. L. Van Slyke, Ph. D., chemist of the New York State Agricultural Experiment Station, Geneva, N. Y., is the first of a series upon various agricultural subjects to be issued by the Office of Experiment Stations for use by the farmers' institute workers in giving instruction in movable schools of agriculture. The need for more extended and specific instruction, outside of regularly organized schools, than is now being given in the farmers' institutes is becoming felt, particularly in those States where the institutes have been longest in operation.

The course in cheese making consists of fourteen lectures, accompanied by fourteen distinct practicums. There are also given lists of references to literature of the subject, as well as of books intended for a library for general use by the students. There is likewise a list of apparatus needed in giving instruction, together with the price of each item.

The plan consists in the formation of classes of not less than eight nor more than fifteen persons who are interested in cheese making, and giving them daily instruction on this subject, continuing for fourteen days, one lecture each day, each lecture to be accompanied by a practicum by the students of from one to two hours under the supervision of the lecturer. The lecturer may also in some cases visit students at their homes and give such particular assistance and advice for the making of cheese as may be best adapted to their individual circumstances and needs.

The equipment of class rooms, apparatus, books of reference, chemicals, and materials (e. g., milk and cream) needed in instruction, together with other incidental expenses, may be provided for by arrangement between the students in each locality and the State director of farmers' institutes. The latter will, however, select the instructor or instructors and provide for their compensation, as far as the laws relating to such work in the several States will permit.

All arrangements for the movable schools are expected to be made by the State director of farmers' institutes, who will plan for such number as he may see fit, and no one should be admitted as a student

in a course who will not first agree in writing to attend every session and perform all of the duties assigned.

Through the instrumentality of these schools it is believed that large numbers of the young men and women who take advantage of the expert teaching thus provided will receive such impressions and acquire such facility in doing the things taught as will result in a greatly improved agricultural practice.

JOHN HAMILTON,
Farmers' Institute Specialist.

COURSE IN CHEESE MAKING FOR MOVABLE SCHOOLS OF AGRICULTURE.

GENERAL SUGGESTIONS TO TEACHERS.

It should hardly be necessary to say that no one should attempt to use this course of lectures for the purpose planned unless he has had extended, practical, and successful experience in making Cheddar cheese. The outlines are to be used as a source of suggestions rather than as a rigid system to be followed in every detail in just the order given. The successful teacher has methods and ideas of his own for imparting instruction and adjusts other systems to his own, selecting what he regards as most useful; but at the same time he must always possess an open mind, ready to appreciate and utilize new suggestions and so more or less constantly modify his own methods in the line of greater efficiency.

Some may think it wise to follow the course in detail in the order given, laying a thorough foundation before taking up the actual details of cheese making. Others may prefer to start with making cheese, calling attention only to general points and from day to day repeating the operation of cheese making with greater attention to minute details. Whatever the order of handling the subject may be, most of the material embodied in the lectures should be utilized, if possible, at some time during the course of instruction.

The ideal conditions for carrying on such instruction are, of course, in a well-equipped cheese factory. The only special requirements will be small vats or a large vat divided into small compartments, so that one can work with 100 pounds of milk, if necessary. For learning the manipulations of cheese making, skim milk will answer every purpose and avoid the risk of wasting whole milk.

The teacher must keep in mind the following facts in imparting knowledge to students: (1) One must know much more than mere methods. It is not sufficient for the teacher or the student to know merely how to make cheese, but for the highest success it is quite as important to know as well the reasons for every step of the methods. Try always to inspire your students with the questioning spirit, so that they will constantly be asking to know "why." (2) One must acquire

the habit of close and accurate observation. This is absolutely essential in successful cheese making, where much depends on being able to observe indications which completely escape any ordinary, untrained observer. (3) Students must be taught the necessity of acquiring the habit of making a careful, accurate record of all observations. Their notes should be inspected from day to day and criticised and discussed. (4) Students must be taught the absolute necessity of appreciating and paying the closest attention to every smallest detail. Cheese making involves many details. While they are not all of equal importance, each must receive its full attention in its proper place. One who can not learn to appreciate and look after details can never make a successful cheese maker. (5) From beginning to end the absolute importance of cleanliness must be impressed in every way possible.

Teachers can not overestimate the necessity of making each student do every detail of work, at first under close supervision, but gradually with a growing degree of independence, as each shows an increasing mastery of the work.

SYLLABUS OF A COURSE OF LECTURES ON CHEESE MAKING.

FIRST LECTURE.

THE COMPOSITION OF COW'S MILK.

It is important to study the material out of which cheese is made in order to understand the changes that take place and the reasons for the operations performed. Illustrate (1) by action of rennet upon the milk casein, and (2) by action of acid upon curd.

1. *Constituents of milk.*—The most abundant constituents of milk are (1) water, (2) fat, (3) calcium casein (casein), (4) albumin, (5) milk sugar, and (6) salts. The compounds of special interest in cheese making are calcium casein, milk fat, milk sugar, salts, and galactase.

2. *Calcium casein.*—Calcium casein (reference No. 1, p. 36),^a ordinarily called casein, is the most important nitrogen-containing compound or proteid contained in milk, (1) because it is the one present in largest quantity and (2) because its properties make possible the conversion of milk into cheese. Calcium casein is a prominent constituent of separator slime, being gelatinous in appearance (reference No. 2, p. 94). It exists in the form of very small, solid, jelly-like particles in suspension and not in solution.

Composition of calcium casein and casein.—Casein contains carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulphur. Casein as such does not exist in milk, but only in combination with about 1.50 per cent of calcium oxid (lime) (reference No. 1, p. 11), this compound being calcium casein.

^a The references in these lectures are to the list given in the appendix, p. 61.

Action of acids on calcium casein.—When an acid is added to milk, its first action is to unite with certain salts of the milk and then with the calcium of calcium casein, forming a precipitate of free casein. On further addition the acid unites with the casein, forming a casein salt of the acid used, as in the case of sour milk, when casein lactate is formed. If a large amount of acid is added to milk, the casein is first coagulated and then dissolved, as in the case of the Babcock test.

Action of alkalis on casein compounds.—Alkalis, like ammonia, caustic soda, carbonate of soda, etc., unite with casein compounds, forming compounds soluble in water. They also dissolve casein coagulated by acids.

Action of heat on casein compounds.—Heat alone under ordinary conditions, even at the boiling point, coagulates calcium casein little, if any. The skim formed on the surface of milk heated above 140° F. contains practically all the constituents of milk and is primarily due to the presence of calcium casein and not to albumin, as formerly supposed.

Action of rennet on calcium casein.—Coagulation by rennet in the presence of soluble lime salts is one of the most characteristic properties of calcium casein. The manufacture of cheese from milk depends upon this property. The compound or curd formed by treating milk with rennet is called calcium paracasein, but does not differ much from calcium casein (reference No. 1, p. 30). The coagulation of calcium casein by rennet is entirely different from that produced by acids (reference No. 1, pp. 22 and 30). The properties of rennet and the conditions that affect its power to coagulate calcium casein will be considered in Lecture 6.

3. *Milk fat or butter fat.*—Milk fat is a mixture of several different compounds, chief of which are palmitin, olein, myristin, and butyrin. Each of these compounds contains glycerin united with an acid (reference No. 3, p. 13), and each varies in its properties from the others (reference No. 3, p. 14). Milk fat in pure, fresh condition is a soft whitish to yellowish mass, of mild taste and only slight odor. It melts easily and is lighter than water. Milk fat is present in milk in the form of minute, transparent globules, averaging about one ten-thousandth of an inch in diameter (reference No. 3, p. 14). The fat globules are not surrounded by any kind of special covering (reference No. 3, p. 14), but are simply minute particles of fat floating free in the form of an emulsion.

The amount of fat in milk is affected by many conditions, among which are individuality, breed, age, stage of lactation, time of milking, and so forth (reference No. 3, pp. 15–17). The direct relation of milk fat to cheese yield will be considered later.

4. *Milk sugar.*—Milk sugar is present in cow's milk in solution. Its importance in relation to cheese making is due to the readiness with

which it is converted into lactic acid by various organisms. (See Lecture 6, paragraph 1.) Experiment—see page 17.

5. *Salts*.—The salts of milk, also called mineral matter or ash, are present in small quantities, but are very important. The relation of the lime (calcium) salts to cheese making will be pointed out later. (Lecture 9, paragraph 3.)

6. *Galactase*.—(See Lecture 6, paragraph 5.)

7. *Amounts of constituents in milk of representative character*.—(a) The average of 5,552 American analyses of milk compiled by the writer is as follows: Water 87.1 per cent, total solids 12.9 per cent, fat 3.9 per cent, calcium casein 2.5 per cent, albumin 0.7 per cent, sugar 5.1 per cent, and ash 0.7 per cent.

(b) Variation in composition of cheese-factory milk during the season (May to October).

In the following table are given the lowest, highest, and average results for the composition of milk during the cheese-factory season:

Variations in composition of milk.

Milk constituents.	Lowest.	Highest.	Average.	Milk constituents.	Lowest.	Highest.	Average.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	86.61	87.71	87.38	Casein.....	2.19	2.66	2.41
Total solids.....	12.29	13.39	12.62	Albumin.....	.58	.88	.72
Fat.....	3.70	4.10	3.73	Sugar, ash, etc....	5.58	6.03	5.76

EXPERIMENT AND PRACTICE WORK, FIRST LECTURE.

Time required for experiments.—The work prescribed in these experiments will require from one to two hours of continuous work, according to the facility of individual students in performing the manipulations. As indicated, a part of the work will be carried over until the day following for final observation.

Apparatus required.—(1) Pipette or graduate to hold 10 cubic centimeters, (2) teacup or glass tumbler or test tube or beaker, (3) common sal soda, (4) whey, and (5) microscope and accessories.

1. *Action of acids on calcium casein (casein) of milk*.—To 10 cubic centimeters of sweet milk in a teacup or glass add 100 cubic centimeters of water. Warm to 100° F. and add some strong vinegar (impure dilute acetic acid) drop by drop, shaking or stirring vigorously. Continue to add vinegar and agitate until a white, solid substance separates. This substance is casein acetate, formed by the union of the acetic acid and the casein of the milk, and it is insoluble in water. Pour off the water from the solid white substance and then add carefully about 15 or 20 cubic centimeters of sulphuric acid such as is used in Babcock test. What happens to the white substance (reference No. 1, p. 21)?

2. *Action of alkalis on casein compounds.*—Prepare some casein acetate, as described in preceding experiment. Dissolve some sal soda in water and add some of this solution to the white, solid casein acetate. Agitate. The casein acetate is dissolved, the casein combining with sodium, forming sodium caseate, which is easily soluble in water.

3. *Preparation of milk sugar.*—Take a pint or more of whey and evaporate it to about one-eighth of its original bulk. Let it stand until the next day. Impure milk sugar separates in solid form. How does it compare in sweetness with cane sugar? Place some of it on a stove or hot iron. What is the odor produced?

4. If a good microscope is available, place one drop of diluted milk (1 part of milk diluted with 10 parts of water) on a glass slide, put a cover glass over it and examine with different magnifying powers. Study the fat globules, noticing their variation in size. Take a small piece of cheese and mix it very completely with several times its bulk of warm water. Then take one drop of this water extract and examine it under the microscope for fat globules. Examine a drop of undiluted whey and of skim milk.

5. Melt about half a pound of butter and pour it into a glass tumbler. Let it stand twenty-four hours at 60° to 80° F. Notice the separation of fat from the brine. Notice the granular structure of the fat and the fact that some of it appears to be more or less liquid through the mass. This shows that butter fat contains different fat compounds.

SECOND LECTURE.

THE COMPOSITION OF COW'S MILK IN RELATION TO THE MANUFACTURE OF CHEESE.

Only within fifteen years has there been a thorough study of the relations of milk to cheese. The whole attention was formerly given to methods of cheese making, and none to such fundamental questions as the relation of fat and casein in milk to yield and quality of cheese, the character and extent of losses of milk constituents in cheese making, their causes and remedies, etc.

1. *Yield of cheese variable with different milks.*—It is a fact of common experience at cheese factories that the amount of cheese made from 100 pounds of milk varies. Provided the conditions of manufacture are the same, such differences are due to differences in the composition of milk.

2. *Yield of cheese dependent upon certain constituents of milk.*—It has been shown that the yield of cheese depends most largely upon the two milk constituents, *fat* and *casein* (reference No. 3, p. 89).

3. *Milk solids divided into two classes.*—We may divide the solids of milk into two general classes: (1) Cheese-producing and (2) whey-producing. The former includes fat and casein; the latter albumin, sugar,

and soluble ash. This division is not strict, since a little fat and casein go into whey and a little albumin and sugar go into cheese. Most of the water of milk goes into whey (reference No. 3, p. 91). On an average 49.5 per cent of the milk solids goes into whey and 50.5 per cent into cheese.

4. *Amounts of milk fat and milk casein in different milks.*—Milk casein varies in amount in different milks, but not as much as fat does. The following table illustrates the relations of fat and milk casein in factory milks:

Fat in milk.	Milk casein in milk.	Fat in milk.	Milk casein in milk.
<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
3.00	2.10	4.00	2.50
3.25	2.20	4.25	2.60
3.50	2.30	4.50	2.70
3.75	2.40		

In general, when the fat in milk increases one-fourth of 1 per cent the milk casein increases one-tenth of 1 per cent (reference No. 3, p. 89). Question: If a normal milk contains 3 per cent of casein, how much fat should it contain?

5. *Increase of cheese yield with increase of fat in milk.*—Fat and casein of milk produce the solid portion of cheese. When fat increases in milk, casein increases also. Hence milk richer in fat produces larger yields of cheese (reference No. 3, p. 90). The yield of cheese from milk varies as the amount of fat and casein in milk vary.

Ratio of fat in milk to yield of cheese.

Fat in milk.	Cheese made from 100 pounds of milk.	Fat in milk.	Cheese made from 100 pounds of milk.
<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>
3.00	8.55	4.00	10.65
3.25	9.10	4.25	11.20
3.50	9.60	4.50	11.70
3.75	10.10		

As the milk grows richer in fat the same amount of milk makes more cheese. Question: How much cheese should be made from normal milk containing 5 per cent of fat? $5\frac{1}{2}$? 6?

6. *Calculation of cheese yield from fat in milk.*—In average factory milk the approximate amount of green cheese from 100 pounds of milk can be found by multiplying the per cent of fat in milk by 2.7 (reference No. 6, p. 433); the amount of ripened cheese is found by multiplying by 2.6. Examples (see p. 19).

7. *Calculation of cheese yield from fat and casein*—A very close approximation to cheese yield from any given milk when the amount of fat and of casein is known

cent of fat in milk by 1.1 and the per cent of casein by 2.5; add the two products thus obtained (reference No. 5, p. 470).

8. *Losses of milk constituents in the manufacture of cheese.*—In 100 pounds of milk about 83 pounds of water go into whey and along with it most of the albumin and sugar and soluble ash. The losses of fat and casein require special consideration.

(a) *Loss of fat.*—The amount of fat lost in whey in cheese making varies from 0.20 to 0.50 and averages 0.33 pound of fat for 100 pounds of milk. The amount of fat lost is practically independent of the amount of fat in milk, as shown by the following table (reference No. 7, p. 214):

Fat in 100 pounds of milk.	Fat lost in whey for 100 pounds of milk.	Fat in milk lost in whey.	Fat in 100 pounds of milk.	Fat lost in whey for 100 pounds of milk.	Fat in milk lost in whey.
<i>Pounds.</i>	<i>Pound.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Pound.</i>	<i>Per cent.</i>
3.0 to 3.5	0.32	9.55	4.5 to 5.0	0.28	5.90
3.5 to 4.0	.33	8.33	5.0 to 5.25	.31	6.00
4.0 to 4.5	.32	7.70			

Examples under paragraph 6, page 18:

(1) How much green cheese can be made from 22,433 pounds of milk containing 4 per cent of fat? How much ripened cheese?

(2) If a cheese maker should make from 1,000 pounds of normal milk, testing $3\frac{1}{2}$ per cent of fat, 75 pounds of cheese, how much cheese per pound of milk fat would there be? How would you account for such a yield of cheese?

Example under paragraph 7, page 18:

A sample of milk contains 4 per cent of fat and $2\frac{1}{2}$ per cent of casein. How much green cheese should be made from 1,000 pounds of such milk?

Example under paragraph 8, above:

(1) A cheese maker makes into cheese 10,000 pounds of milk containing 3.7 per cent of fat. He produces 1,000 pounds of cheese containing 35 per cent of fat. (a) How many pounds of fat have been lost? (b) How much fat per 100 pounds of milk? (c) What percentage of fat in the milk is lost?

The old belief that all fat in milk over 3.5 per cent is inevitably lost in cheese making is fully disproved. The loss of fat in cheese making occurs mechanically. The fat globules on the cut surfaces of the curd are disengaged from these free surfaces and go into the whey. Following are some of the conditions that increase loss of fat in cheese making: (1) Any condition that interferes with complete coagulation by rennet, such as dilution with water, presence of preservatives like salt, formalin, etc. (2) Abnormal composition of milk, in which the casein is abnormally low in comparison with fat. (3) Jarring or stirring milk after rennet coagulation has commenced and before it is

completed. (4) Cutting curd where too soft. (5) Violent, careless, and rapid motions of knife in cutting curd. (6) Heating curd too rapidly or to too high temperature. (7) Piling curd too much. (8) Putting curd to press too warm. (9) Too rapid application of pressure in hoop. (10) Fermentations that produce floating curds or excessive acidity or that dissolve any casein. Experiments bearing on these points will be given later in their appropriate connection.

(b) *Loss of casein in cheese making.*—The casein lost in cheese making is lost mostly in the form of fine particles of coagulated paracasein, which pass through the strainer when the whey is removed from the curd. This loss is not entirely avoidable, but is made greater by carelessness or violence in cutting curd and in subsequent handling, by agitation while drawing off whey, and by imperfect strainers. Any condition that interferes with the complete coagulation of the milk casein by rennet causes loss of casein. The average loss of casein in cheese making is 0.10 to 0.15 pound for 100 pounds of milk (reference No. 3, p. 92).

9. *Distribution of milk constituents of 100 pounds of milk in whey and cheese.*—The following table illustrates what becomes of the constituents of milk in the operation of cheese making:

		Water.	Milk solids.	Fat.	Casein.	Albumin.	Sugar, ash, and acid.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pound.	Pounds.
Milk.....	100.00	87.00	13.00	4.00	2.50	0.75	5.75
Whey.....	89.35	83.00	6.35	.30	.10	.70	5.25
Cheese.....	10.65	4.00	6.65	3.70	2.40	.05	.50

10. *The relation of composition of milk to composition of cheese in the case of normal milk.*—Milk rich in fat as compared with milk poor in fat produces cheese containing more fat in proportion to water and paracasein compounds. The composition of cheese depends on the composition of milk, provided the cheese making is normally done. The following table illustrates these statements in the case of freshly made cheese:

Fat in milk.	Water in cheese.	Fat in cheese.	Paracasein compounds in cheese.	Fat in milk.	Water in cheese.	Fat in cheese.	Paracasein compounds in cheese.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
3.00	39.4	32.2	23.4	4.00	37.3	35.2	22.5
3.25	39.0	32.9	23.1	4.25	37.0	35.7	22.3
3.50	38.1	33.9	23.0	4.50	36.5	36.3	22.2
3.75	37.5	34.7	22.8				

11. *The relation of composition of milk to composition of cheese in the case of skimmed milk.*—The removal of fat from milk reduces the amount of fat in relation to casein, since only a little casein is removed with fat. The effect of skimming milk is illustrated in the case of milk

containing normally 4 per cent of fat and 2.50 per cent of casein (reference No. 3, p. 94).

	Pounds of fat removed from 100 pounds of milk.	Pounds of fat left in 100 pounds of milk.	Pounds of casein in milk.	Pounds of casein for 1 pound of fat.
Normal milk.....	0.00	4.00	2.50	0.63
Skimmed milk.....	.50	3.50	2.50	.71
Do.....	1.00	3.00	2.50	.83
Do.....	1.50	2.50	2.50	1.00
Do.....	2.00	2.00	2.50	1.25
Do.....	2.50	1.50	2.50	1.67
Do.....	3.00	1.00	2.50	2.50
Do.....	3.50	.50	2.50	5.00
Do.....	4.00	.00	2.50	.00

The figures below give the practical composition of green cheese made from normal and skim milks:

	Pounds of fat removed from 100 pounds of milk.	Pounds of fat left in 100 pounds of milk.	Per cent of fat in cheese.	Per cent of water in cheese.	Per cent of paracasein compounds in cheese.
Normal milk and cheese.....	0.00	4.00	37.3	35.2	22.5
Skim milk and cheese.....	1.00	3.00	31.4	37.4	26.2
Do.....	2.50	1.50	19.0	44.4	31.6
Do.....	3.50	.50	7.3	50.7	37.0

12. *The relation of composition of milk to composition of cheese in the case of milk containing added cream.*—Addition of cream to normal milk produces upon cheese the opposite effect from skimming—that is, increases the proportion of fat in cheese in relation to water and paracasein compounds (reference No. 3, p. 94).

13. *Standard of composition for whole-milk cheese.*—Cheese properly made from normal milk rarely, if ever, contains less than 32 per cent of fat. Of the total solids in cheese (fat, paracasein compounds, and ash) not less than 50 per cent should be fat (reference No. 3, p. 95).

14. *Composition of whey.*—The composition of whey varies according to the composition of the milk from which it comes and also according to conditions of cheese making. The following table illustrates extreme variations in cheese-factory whey:

	Average.	Highest.	Lowest.		Average.	Highest.	Lowest.
	Per cent.	Per cent.	Per cent.		Per cent.	Per cent.	Per cent.
Water.....	93.04	93.57	92.48	Albumin.....	0.72	0.90	0.45
Total solids.....	6.96	7.52	6.43	Sugar.....	4.00	4.50	3.50
Fat.....	.36	.55	.23	Lactic acid.....	.20	.25	.16
Casein.....	.10	.15	.05				

The amount of lactic acid in whey varies greatly, according to the time the determination of acidity is made. The acidity of whey when

just removed from curd may vary from 0.10 to 0.15, and this will increase up to the end of the cheese-making process. Fresh whey shows less acid than the milk from which it comes, because the whey does not contain the calcium casein of the milk, this compound by itself showing an apparent acidity of 0.08 or 0.09 per cent.

15. *Composition of cheese.*—The following figures give the average composition of cheese when green and when ripened:

	In green cheese.	In ripened cheese.		In green cheese.	In ripened cheese.
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
Water.....	36.80	31.75	Paracasein, etc.....	23.75	25.50
Solids.....	63.20	68.25	Ash, acid, etc.....	5.70	6.00
Fat.....	33.75	36.75			

16. *The value of cheese as food.*—Cheese is one of our most concentrated and cheapest forms of food and furnishes a large amount of protein (reference No. 3, p. 98).

EXPERIMENT AND PRACTICE WORK, SECOND LECTURE.

Time required for experiments.—The actual work required in getting the experiments started may not occupy more than half an hour, if one determines solids in only one sample of milk and whey, but the work can not be completed until three or four hours later, when evaporation is complete. It will be well to make several different determinations either on the same or on different samples.

Apparatus required.—(1) Testing scale with set of metric weights weighing to 10 milligrams. (2) Small, flat-bottomed evaporating dishes 2½ or 3 inches in diameter. Small, granite-iron or tin dishes will answer. (3) An arrangement for heating these dishes directly over boiling water or live steam. A pail could be used provided with a close-fitting cover, in which are cut holes nearly as large in diameter as the small evaporating dishes used.

1. *Approximate determination of milk solids.*—Weigh a small granite-iron or bright tin basin, run in 10 cubic centimeters of milk and weigh again. (Weigh to within 10 milligrams.) Then heat the dish over live steam or boiling water for three or four hours. After wiping dry and cooling weigh again. Subtract the weight of the dish from the last weight, which gives weight of dried milk or milk solids. Divide this by weight of milk used. The result is the per cent of solids in milk. While the appliances used will not give accurate results, it is desirable to go through the work to know something of the method of determining solids.

ILLUSTRATION.

	Grams.
Weight of dish.....	101. 55
Weight of milk and dish.....	111. 25
Weight of milk used.....	10. 30
Weight of dish and dried milk (solids).....	102. 85
Weight of dish and solids less weight of dish.....	$102. 85 - 101. 55 = 1. 30$
Hence, 10. 3 grams of milk contain 1. 3 grams of solids.	
$1. 3 \div 10. 3 = 12. 62$ per cent of solids in milk.	

2. *Determination of whey solids.*—Follow instructions given under preceding experiment, using, if possible, whey produced by same lot of milk used above.

ILLUSTRATION.

	Grams.
Weight of dish.....	101. 55
Weight of whey and dish.....	111. 83
Weight of whey used.....	10. 28
Weight of dish and dried whey (solids).....	102. 20
Weight of dish and solids less weight of dish.....	$102. 20 - 101. 55 = 0. 65$
$0. 65 \div 10. 28 = 6. 32$ per cent of solids in whey.	

3. *To determine per cent of cheese solids in milk.*—Subtract per cent of whey solids from per cent of milk solids.

ILLUSTRATION.

	Per cent.
Milk solids.....	12. 62
Whey solids.....	6. 32
Cheese solids.....	6. 30

THIRD LECTURE.

CARE OF MILK TO BE USED IN CHEESE MAKING.

1. *Necessity of clean milk.*—One of the fundamental conditions of successful cheese making is clean milk. Milk may appear to be in good condition when being made into cheese, but may contain organisms that develop later in and spoil the cheese.

2. *Sources of contamination.*—Assuming that milk is in every way normal as it leaves the udder of the cow, it may later become unfit for cheese making by the presence of bad odors and tastes, resulting from (1) food eaten, (2) flavors absorbed, and (3) bacterial infection. Other conditions apart from bad flavors, such as souring, make milk unfit for Cheddar cheese making.

3. *Flavors from foods eaten.*—Certain foods that have strong taste and odor impart to milk their characteristic flavors. Most common among these are onions, garlic, turnips, cabbages, ragweed, etc. (references No. 3, p. 25; No. 8, p. 13, and No. 9, p. 61).

4. *Absorption of flavors by milk.*—Milk, particularly if warm, absorbs odors present in the surrounding air. The most common sources of such odors are the manure in unclean stables and any strongly fla-

vored food present in the stable during milking, such as silage (references No. 3, p. 25; No. 8, p. 13, and No. 10, p. 104).

5. *Injurious flavors from bacterial infection.*—The most common source of milk contamination is from bacteria. These get into the milk ducts of the udder and contaminate the first milk drawn (references No. 9, p. 36, and No. 11, p. 39). After the milk is drawn bacteria get into it (1) from the cow (references No. 9, p. 44, and No. 11, p. 41); (2) from the air (references No. 9, p. 43, and No. 11, p. 45); (3) from the milk vessels (references No. 9, p. 44, and No. 11, p. 34), and (4) from the milkers (references No. 3, p. 24; No. 9, p. 44, and No. 11, p. 41).

6. *Characteristics of bacteria.*—Bacteria are very small, colorless plants, invisible to the unaided eye. They are extremely numerous and widely distributed in soil, air, and water. In shape they are spherical, rod-shaped, and spiral (references No. 9, p. 20, and No. 11, p. 2). They multiply by simple division with great rapidity (references No. 9, p. 26, and No. 11, p. 4). Bacteria require as food compounds containing nitrogen, carbon, hydrogen, oxygen, and inorganic matter (references No. 9, p. 28, and No. 11, p. 7). The sugar, casein, and albumin in milk and its products furnish available food for bacteria. Bacteria grow only within certain ranges of temperature, the most favorable temperatures being between 80° and 95° F. for those common in milk (references No. 9, p. 29, and No. 11, p. 8). All bacteria are destroyed at the temperature of boiling water (reference No. 9, p. 29) and by many chemical substances called antiseptics (reference No. 11, p. 18). Bacteria are always associated with filth, absence of sunlight, and impure air.

7. *Obtaining clean milk.*—Milk produced for use in cheese making should be kept fairly free from bacteria, and the rapid growth of those in the milk should be retarded. The number of bacteria in milk can be largely reduced by the following precautions: (1) Every condition in and about the stable should be regulated with reference to an abundant supply of pure air, a direct exposure to sunlight, and the absence of dust or any form of dirt. No manure or stagnant water should be near the barn. The barnyard should be distant from the milking stall (reference No. 9, p. 48). (2) Keep the body of the cow as free as possible from every form of dirt, dust, and loose hairs (reference No. 9, p. 47). (3) Before milking, the cow's udder should be properly cleaned and the milker should have clean hands and clothing (reference No. 9, p. 44). (4) The milk vessels must be kept bacteriologically clean (reference No. 9, p. 44). The water used in washing vessels should be free from unhealthful contaminations (reference No. 9, p. 51). (5) Milk pails should be used offering the least exposure of surface of milk (reference No. 9, p. 52). (6) After milking a pailful remove the milk from the barn

to a clean dry room, strain carefully, and cool to 60° F., if possible, to prevent too rapid growth of bacteria. The aeration of milk before cooling should be done, if at all, only in air comparatively free from bacteria and never in the stable (reference No. 9, p. 55). After the milk has been cooled to 60° F. it should be covered to prevent evaporation and consequent thickening of layer of cream (reference No. 8, p. 17).

8. *Cleanliness in cheese factory.*—Cleanliness in a cheese factory is just as important as in the barn. Good milk can not be made into good cheese in a dirty factory. The inside and outside of weighing can, cheese vats, etc., must be kept strictly clean. The floors must be scrubbed thoroughly (reference No. 8, p. 19). Sal soda is in many cases a cheap substitute for soap, not only dissolving grease, but neutralizing acids and loosening dirt. Everything possible must be done to prevent any accumulation of dirt in corners. All cloth materials used must be thoroughly boiled at frequent intervals. All drains should be kept disinfected (reference No. 8, p. 20).

EXPERIMENT AND PRACTICE WORK, THIRD LECTURE.

Time required for experiments.—Four hours at least will probably be required to get the work started and much more will be needed to become at all skillful.

Apparatus required.—(1) 1 cubic centimeter pipettes inclosed in glass tubes for sterilizing; (2) small flasks marked to hold 99 cubic centimeters; (3) small homeopathic vials, some marked to hold 19 and some 5 cubic centimeters; (4) absorbent cotton; (5) peptone-agar culture medium; (6) Petri dishes, and (7) test tubes.

1. *General outline of method used in determining the number of germs in milk.*—The method of finding out how many bacteria are present in milk is based upon placing a small amount of milk upon a sterile substance which will enable the bacteria to grow. After 24 to 36 hours small spots appear and their number is greater or less according to the number of bacteria in the milk (references No. 9, pp. 251–266, and No. 11, p. 32).

2. *Sterilizing milk.*—Determine the acidity of some milk and put some in a half dozen test tubes and plug the tubes with absorbent cotton. Then place in boiling water thirty minutes. Let them stand at room temperature. At the end of four days determine the degree of acidity in tube No. 1; at the end of eight days determine the acidity in No. 2, and continue examining at intervals of four days until all have been examined. Do not remove the cotton plug from any tube until you are ready to examine at once.

Sterilize a portion of some milk and then allow sterilized and unsterilized portions to stand uncovered at room temperature. Examine each day and notice when each coagulates.

3. *Showing relative number of bacteria in different milks.*—(Reference No. 9, p. 252, etc.)

(a) Sterilize all apparatus used in an oven at a temperature of 300° to 350° F. for an hour.

(b) Culture medium had better be prepared in advance by some one familiar with methods (reference No. 9, pp. 253–257), as it will hardly be practicable for each student to acquire proper training in the short time allowed for the work.

(c) Put some water in the flasks marked to hold 99 cubic centimeters, sterilize by steaming two hours, and cool. Then to this add 1 cubic centimeter of the milk to be examined and shake thoroughly (reference No. 9, p. 258).

(d) Melt the agar culture contained ready for use in a test tube by placing the tube in warm water. Then add 1 cubic centimeter of the diluted milk to the agar culture in the test tube, shake thoroughly, but gently. Then pour the contents into a Petri dish (reference No. 9, pp. 258, 259), put cover on dish, and set aside at a temperature of 70° to 80° F.

(e) Examine Petri dishes containing milk and agar culture daily for four or five days. Notice the number of spots (reference No. 9, p. 260).

4. *Examine in the manner indicated above milk* obtained in the following manner: (1) Milk from an uncleaned cow kept in a dirty, dusty stable, and (2) milk from a cow carefully cleaned before milking and milked in a clean place free from dust.

FOURTH LECTURE.

THE USE OF THE BABCOCK METHOD OF TESTING MILK IN CONNECTION WITH THE MAKING OF CHEESE.

1. *What the Babcock test is.*—The Babcock test is a method for determining the amount of fat in milk and its products. The test is based on the action of strong sulphuric acid upon the solids of milk other than fat, by which the milk fat is released from the restraining influence of the other compounds and so is free to collect in one separate mass, centrifugal force being employed to complete the separation.

2. *Advantages of test.*—The Babcock test possesses the following advantages: (1) Inexpensiveness, (2) accuracy, (3) rapidity, (4) ease and simplicity, (5) direct results, (6) applicable at once to many samples, (7) results easily confirmed, and (8) applicable not only to milk, but to products (reference No. 3, p. 100).

3. *Disadvantages of test.*—(1) Acid used is dangerous to handle and so requires caution, (2) strength of acid must be examined and kept uniform, (3) speed of centrifugal must be properly regulated, (4) temperature of milk must be under control, (5) graduated glassware may be incorrect, and (6) every detail must be carefully performed (reference No. 3, p. 101).

4. *Opportunities for use in cheese making.*—The Babcock test finds occasion for use in cheese making as follows: (1) Testing milk of individual patrons when the dividends are made on the basis of the milk fat, (2) testing milk to ascertain if it has been seriously skimmed, (3) testing milk to use fat as a basis for estimating yield of cheese and regulating amount of salt used, (4) testing whey and press drippings to ascertain if fat loss is excessive, and (5) testing cheese for amount of fat.

5. *Apparatus and materials used in testing milk.*—The following list includes the apparatus and materials used in testing milk: (1) Test bottles, graduated from 0 to 10 per cent, so that each division represents two-tenths of 1 per cent when 17.5 cubic centimeters (18 grams) of milk are used; (2) pipette for measuring milk, holding 17.6 cubic centimeters to mark; (3) measure for acid, holding 17.5 cubic centimeters to mark; (4) centrifugal machine, having a wheel 12 to 20 inches in diameter, easily capable of being run at a speed of 700 to 1,200 revolutions a minute, and (5) commercial sulphuric acid having a specific gravity above 1.82 and below 1.83, preferably just 1.825. [The lecturer should have all the apparatus and materials at hand and explain each in full detail.] (Reference No. 3, p. 101, or No. 12, pp. 34–54.)

6. *Sampling milk for testing.*—Milk that has soured and thickened or on the surface of which cream has risen and dried somewhat, or milk the fat of which has partially churned, is difficult to sample; but these difficulties should not be common in cheese-factory work. The samples to be tested must be thoroughly mixed (reference No. 3, p. 103, or No. 12, p. 26).

7. *Composite samples.*—In order to avoid testing milk daily, composite samples may be prepared and tested for a week or ten days. Much care should be used in preparing and keeping composite samples (reference No. 3, p. 110, or No. 12, p. 134). For use of milk thief in taking composite samples, see reference No. 8, p. 29.

8. *Performing test.*—Following are the steps to be followed in testing milk: (1) Running sample of milk into test bottle (reference No. 3, p. 104, or No. 12, p. 28). (2) Adding acid to milk in test bottle (reference No. 3, p. 104, or No. 12, p. 28). (3) Mixing milk and acid (reference No. 3, p. 105, or No. 12, p. 30). (4) Whirling test bottles and adding water (reference No. 3, p. 105, or No. 12, p. 31). (5) Measuring fat (reference No. 3, p. 106, or No. 12, p. 32). [The lecturer should perform and explain every operation in detail, making clear the reasons for each step. He should then require each student to go through and explain each detail until an independent degree of skill has been attained.]

9. *Testing whey by Babcock method.*—The test is conducted in the usual way, but special bottles having small necks should be used (reference No. 3, p. 108, or No. 12, p. 74).

10. *Determining fat in cheese by Babcock method.*—The method is less satisfactory, owing to difficulty of sampling cheese. It is necessary to weigh the cheese, using about 5 grams. Then add 15 cubic centimeters of hot water and shake to an emulsion. Then add acid and proceed as before. The per cent of fat read on bottle must be multiplied by 18 and divided by the number of grams of cheese used (reference No. 3, p. 109, or No. 12, p. 77).

EXPERIMENT AND PRACTICE WORK, FOURTH LECTURE.

Time required.—One's first test can probably be made in twenty minutes, but the details should be often repeated so that one can acquire rapidity and accuracy. It would be well to devote two hours the first day to the test and then use the test afterwards every day as opportunity offers.

Apparatus and materials required.—See paragraph 5, preceding. In addition, 1 "N-H" milk-bottle tester.

1. *Use of pipette.*—Practice drawing milk into pipette and bringing to mark until it can be done quickly and accurately (reference No. 12, p. 27).

2. *Running milk into test bottle from pipette.*—After filling pipette properly run milk into test bottle, so that milk will all be delivered without running over (reference No. 3, p. 104, or No. 12, p. 128).

3. *Measuring acid and pouring into test bottle.*—(Reference No. 3, p. 104, or No. 12, p. 28.) Practice pouring acid into bottle so that it will run down side of bottle and form a layer under the milk without mixing with it. *In handling sulphuric acid be careful not to get it on the skin or clothing.*

4. *Mixing milk and acid.*—(Reference No. 3, p. 105, or No. 12, p. 30.) Practice giving the bottles the peculiar kind of rotary motion that mixes the milk and acid without throwing any out of the bottle.

5. *Whirling test bottles and adding water.*—(Reference No. 3, p. 105, or No. 12, p. 31.) Observe carefully precautions as to rapidity of revolution. Determine number of revolutions made per minute (reference No. 12, p. 50) in relation to number of turns of handle.

6. *Measuring fat.*—Practice reading fat in graduated neck (reference No. 3, p. 106, or No. 12, p. 32).

7. *Measuring accuracy of test bottles.*—Use brass plunger milk-bottle tester according to directions given with the apparatus.

8. *Testing other substances than milk for fat.*—After acquiring facility in making tests with milk test skim milk, whey, butter, and cheese (reference No. 3, pp. 108, 109, or No. 12, pp. 74–77).

FIFTH LECTURE.

OTHER TESTS USED IN CONNECTION WITH CHEESE MAKING.

In addition to determining fat there are some other forms of tests of value in connection with cheese making, and some of these will be considered here.

1. *Use of lactometer in determining solids of milk.*—The specific gravity of milk is the weight of a given bulk of milk as compared with the weight of an equal bulk of water at the same temperature. The specific gravity of milk averages about 1.032. Fat, being lighter than water, decreases specific gravity, while such compounds as casein and milk sugar, being heavier than water, increase the specific gravity (reference No. 3, p. 113). The specific gravity is found out by means of a lactometer. Two forms are in common use, the Quevenne lactometer (reference No. 3, p. 43) and the board of health lactometer (reference No. 3, p. 114). The lactometer is used as follows in determining solids of milk: Rule 1. To find the per cent of total solids in milk multiply the per cent of fat by 1.2 and add the result to one-fourth of the lactometer (Quevenne) reading (reference No. 3, p. 114). [Examples should be given and actual determinations should be made by the lecturer and then by each student.]

2. *Testing acidity of milk and whey.*—The method of testing acidity in milk or whey is based upon the chemical action taking place between acids and alkalis (reference No. 3, p. 111). Acids and alkalis neutralize each other and form compounds called salts, which are neither acid nor alkaline, but neutral. An indicator is a substance used to tell whether a solution is acid, alkaline, or neutral. The most common indicator is phenolphthalein, which turns pink in alkali solutions and colorless in acid or neutral solutions. For use, 1 gram of phenolphthalein is dissolved in 50 cubic centimeters of strong alcohol and 50 cubic centimeters of water. Only a few drops need be used (reference No. 3, p. 111). The two forms of acid test in common use are those devised by Mann and by Farrington.

(a) Mann's acid test (reference No. 3, p. 112, or No. 12, p. 96). Measure just 50 cubic centimeters of milk or whey into a clean porcelain cup or glass. Add a few drops of phenolphthalein and then let in from a burette, previously filled to zero point, a little neutralizer. A pink color appears and then disappears on stirring. Add a little more neutralizer and stir. Continue this until the pink color remains even after considerable stirring. Look at burette and see how many cubic centimeters of alkali have been used. Suppose 10 cubic centimeters of "neutralizer" have been used to neutralize the milk or whey, then multiply 10 by .018 and the result is 0.18, which is the per cent of lactic acid in the milk or whey.

(b) Farrington's alkaline tablet test. In this form of test the alkali and indicator (phenolphthalein) are mixed together in the form of

solid tablets. One tablet is dissolved so as to make 100 cubic centimeters of solution, which is added in small amounts to 17.6 cubic centimeters of milk or whey until the pink color remains. Each cubic centimeter of solution used stands for 0.01 per cent of lactic acid. Thus a milk using 15 cubic centimeters of alkali solution contains 0.15 per cent of acid (reference No. 3, p. 112, or No. 12, p. 99). Some precautions must be used about keeping tablets dry until used, and solutions a day old should not be used.

[Suggestions to lecturer: Make sure that the relation of acids and alkalis and the use of indicators are understood by the student. Perform the test (one or both), explaining each step, using milk from fresh to sour and also whey from fresh to a day old. Also have each student make several tests, so as to become familiar and accurate in the manipulation. Impress the necessity of using exact quantities.]

3. *Methods of testing rennet extracts.*—The rennet test is a method for ascertaining in what time a definite amount of rennet extract will coagulate a certain amount of milk at a given temperature. It is of value for learning the strength of rennet extract and the ripeness of milk. Two forms are in common use—(1) the Monrad test, and (2) the Marschall test.

(a) The Monrad rennet test (reference No. 3, p. 67, or No. 8, p. 38). The conditions used in this test are as follows: Amount of milk used, 160 cubic centimeters; temperature of milk, 82° to 86° F.; amount of rennet, one-half of 1 cubic centimeter diluted with 5 cubic centimeters of water. The diluted rennet is added to the milk at the fixed temperature, stirred in, and the time noted by the second hand of a watch. The time is again noted when the milk has coagulated. The more quickly the coagulation takes place the stronger the rennet. Precautions to be used in comparing rennet extracts: (1) Use the same milk if possible, (2) and the same degree of temperature. Special apparatus for this can be purchased.

(b) The Marschall test (reference No. 3, p. 68, or No. 8, p. 39). In this test the same general rules of procedure apply, but the coagulation takes place in a cup having on its sides graduated lines and in the bottom a glass tube with a very small bore. After the rennet is added the glass tube is opened and the milk allowed to trickle out until it coagulates and ceases to run. The marks made inside the cup show how much milk has run out. The stronger the action of the rennet the more quickly the milk coagulates, the less runs out, and the fewer spaces are uncovered. One disadvantage of the test is that the bore of the glass tube differs in different cups, which makes difference in results. In trying different cups for comparison, always use the same sample of milk. The Marschall test is convenient for ordinary factory work, but it is not capable of so great delicacy as the Monrad test.

[Suggestion to lecturer: Have apparatus for both of these tests. Perform tests before students and then have each student perform the tests. Use milks of different age in the test. Have different students compare results on the same sample of milk.]

4. *Detection of injurious ferments in milk.*—The “Wisconsin curd test” is a method for detecting milks that are undesirable for cheese making (reference No. 3, p. 64, or No. 8, p. 15). The test consists in making a small chunk of cheese curd from milk in a glass jar. Pint fruit jars with small holes in the covers are sterilized in boiling water and then nearly filled with the milks to be tested and placed in water at 95° to 100° F. Ten drops of rennet are added to each jar and mixed. After curdling, the curd is cut into small pieces and stirred, the whey being poured off from time to time until the curd mats. The curd is then kept at about 95° F. for six or eight hours and then examined. Injurious forms of ferments in milk are indicated when the curd is spongy in texture and very full of holes or “mushy” in texture or offensive to smell. This test is of value in detecting individual herds and even individual cows, whose milk is not good for cheese making.

[Suggestions to lecturer: This test should be performed on different milks, some of which have been treated so as to be made bad. Each student should be required to perform the details until they are familiar. Every milk used in cheese making by the students should be examined by this test, and it should be applied at times to the milk of each herd.]

5. *The hot-iron test.*—(References No. 3, p. 74, and No. 8, p. 61.) The hot-iron test is a means of measuring roughly the amount of paracasein that has been formed from calcium paracasein or of the amount of acid that has been formed and combined with calcium of calcium paracasein. It does not indicate the amount of acid present in the whey. The test is made as follows: A small mass of curd is pressed in the hand to remove the whey and is then pressed against a bar of iron heated a little short of redness and then drawn away carefully. Fine silky strings adhere to the iron, the length depending mainly on the amount of free paracasein present in the curd. Samples of pure paracasein may be drawn out in strings a foot or more long when tested by the hot iron. Uncombined casein behaves the same way (reference No. 1, pp. 16, 28).

EXPERIMENT AND PRACTICE WORK, FIFTH LECTURE.

Time required.—Four hours can well be devoted to work on the different tests described, getting familiar with details, so that one can apply them daily in regular work.

Apparatus and materials required.—(1) Quevenne lacto-thermometer, (2) New York State Board of Health lacto-thermometer, (3) glass

cylinder or jar 11 inches by 2 inches, (4) Mann's acid test outfit, (5) Farrington's alkaline tablet test outfit, (6) Wisconsin curd test outfit, and (7) rennet extract.

1. *Use of lactometer.*—(Reference No. 3, pp. 113–114, or No. 12, pp. 80–93.) Use both Quevenne and New York State forms of lactometers. The lacto-thermometer forms are preferable. (1) Test lactometers in water at different temperatures. (2) Do the same in milk and whey. (3) Calculate per cent of total solids in different samples of milk from lactometer reading and per cent of fat. Calculate per cent of solids-not-fat.

2. *Action of acids and alkalis on each other.*—Add 1 cubic centimeter of sulphuric acid to 100 cubic centimeters of water and mix by shaking. Then dissolve 5 alkaline tablets in 85 cubic centimeters of water. Take 20 cubic centimeters of the dilute sulphuric acid in a teacup and add to it 5 drops of solution of phenolphthalein. Then add the alkali solution gradually, shaking after each addition and continuing until the pink color remains instead of disappearing on shaking. Then add 1 cubic centimeter of dilute acid and note the disappearance of color. Add more alkali until color reappears. What chemical change takes place when the alkali is added to the acid? Does the acid combine with the alkali? Is the acid all combined with acid when the pink color appears? Do acids form color with phenolphthalein? Do alkalis form color with phenolphthalein? (Reference No. 3, p. 111.)

3. *Mann's acid test.*—(Reference No. 3, p. 112, or No. 12, p. 96.) Carry out details of Mann's acid test with (a) milk, (b) whey, examining them at intervals of an hour.

4. *Farrington's alkaline tablet test.*—(Reference No. 3, p. 112, or No. 12, p. 99.) Use this test in same manner as preceding.

5. *Monrad rennet test.*—(Reference No. 3, p. 67, or No. 8, p. 38.) Apply the test as described to the same milk at intervals of thirty minutes for two or three hours, letting milk stand at temperature of 80° to 85° F.

6. *Marschall rennet test.*—(Reference No. 3, p. 68, or No. 8, p. 39.) Apply to same milk at intervals of thirty minutes, letting milk stand at temperature of 80° to 85° F.

7. *Wisconsin curd test.*—(Reference No. 3, p. 64, or No. 8, p. 15.) Apply this test to milk of different herds of cows, noticing whether there is any relation between the results and the cleanliness of the stables in the case of the individual herds.

8. *Hot-iron test.*—Prepare cheese curd with rennet and test from time to time on hot iron (references No. 3, p. 74, and No. 8, p. 61).

SIXTH LECTURE.

THE RELATION OF BACTERIA AND ENZYMES TO CHEESE MAKING.

1. *Bacteria needed for cheese making.*—For the successful making of Cheddar cheese lactic-acid bacteria are necessary (reference No. 9, p. 248). There are many varieties of these bacteria, but they are alike in being able to convert milk sugar into lactic acid. The acid of milk is noticeable to the taste when it reaches 0.3 per cent. The milk begins to thicken when the acid reaches 0.4 per cent, and above 0.5 per cent the curd becomes solid. The chemical action of the lactic acid is given in Lecture 1, paragraph 3. Less than one-half of 1 per cent of milk sugar is required to furnish the lactic acid needed in making cheese. The most favorable temperature for growth of the bacteria is 90 to 95° F. (references No. 3, p. 26, and No. 9, p. 64). The lactic-acid bacteria are of value by preventing the growth of injurious forms of fermentation.

[Suggestions to lecturer: Have each student determine the amount of acid (see Lecture 5, paragraph 2) in fresh milk, and then at hourly intervals at room temperature for six or eight hours.]

2. *Bacteria undesirable for cheese making.*—Among bacterial ferments that act injuriously in cheese making are the following: (1) Those producing gas abundantly, and thereby causing "floating" curds and "huffing" cheese (references No. 9, p. 69, and No. 11, p. 169); (2) those digesting the curd; (3) those producing offensive flavors (reference No. 11, p. 177); and (4) those producing poisonous products (reference No. 11, p. 179). Many injurious fermentations can be detected. (See Lecture 5, paragraph 4.)

3. *Two classes of ferments.*—Two classes of ferments are recognized: (1) Organized and (2) unorganized. Organized ferments are living organisms capable of producing fermentations, such as bacteria (reference No. 3, p. 22). An unorganized ferment or enzyme is a chemical substance or ferment without life, capable of causing many changes, the enzyme itself undergoing little or no change. They are produced by bacteria and in higher forms of plants and animals. There are two enzymes of special interest in cheese making: (1) Rennet enzymes and (2) galactase.

4. *Rennet enzyme* is an unorganized ferment capable of coagulating the calcium casein of milk. On account of this property rennet is a fundamental substance in Cheddar cheese making. Rennet is used in the form of an extract.

(a) Source of rennet extract. The usual source is the fourth stomach of a suckling calf. The enzyme may be extracted by treatment with dilute salt water. Reliable commercial rennet extracts are preferable to home-made extracts, being of more uniform strength. Rennet should be kept in a cool, dark place (references No. 8, p. 32, and

No. 3, p. 65). For method of testing strength of rennet extracts, see Lecture 5, paragraph 3. The enzyme contained in rennet extract is essentially the same as pepsin.

(b) Strength of rennet to coagulate milk. One part of good commercial rennet extract, which is only a dilute form of rennet enzyme, readily coagulates five thousand parts of milk (reference No. 3, p. 66).

(c) Chemical action of rennet. When rennet coagulates the calcium casein of milk it forms a substance called calcium paracasein, which is in general properties about like calcium casein. Cheese curd is an impure form of calcium paracasein. This is quite different from the solid substance formed by calcium casein when treated with acids.

5. *Conditions of rennet action.*—The conditions of rennet action should be carefully studied in an experimental way.

(a) Acids affect action of rennet. Milk must be neutral or acid for coagulating action of rennet. Rennet will not coagulate milk having an alkaline reaction. Increased amounts of acid increase the rapidity and completeness of coagulation (reference No. 3, p. 66, or No. 8, p. 40).

(b) Temperature affects time of coagulation by rennet. The quickness of coagulation increases with increase of temperature (reference No. 3, p. 66, or No. 8, p. 41). The character of coagulated substance is soft and loose when coagulation takes place below 60° F. or above 120° F. At 77° to 110° F. the curd is firm and solid. Heating rennet above 120° F. weakens its coagulating power.

(c) Strength and amount of rennet extract. Strength of rennet extract, as well as increased amounts of rennet, increases the rapidity and completeness of coagulation (references No. 3, p. 66, and No. 8, p. 42). Dilution of milk by water decreases rapidity of rennet action.

(d) Action of rennet is affected by different chemical compounds added to milk. Rennet coagulation is delayed by common salt, formalin, borax, and other substances (references No. 3, p. 67, and No. 8, p. 43).

(e) Effect of heating milk upon rennet action. When milk is heated above 150° F. for some time it coagulates less quickly than unheated milk. Boiled milk coagulates slowly or not at all. Coagulation may be restored by addition of acid (reference No. 3, p. 67).

(f) The relation of soluble lime (calcium) salts to rennet coagulation. Rennet will not coagulate milk when soluble lime salts are not present. Rennet coagulation occurs in two stages: (1) Rennet changes calcium casein into calcium paracasein, but no coagulation takes place; (2) coagulation occurs in the presence of soluble lime salts (reference No. 1, p. 23).

The action of acid in hastening rennet action is explained by the increased formation of soluble lime salts. Boiling milk lessens the amount of soluble lime salts, and so interferes with action of rennet.

Addition of acid to boiled milk makes lime salts soluble again and restores power of rennet coagulation.

(g) Milk from different cows of the same herd coagulates with rennet in quite varying periods of time (reference No. 3, p. 67).

6. *Galactase* is an enzyme existing naturally in milk. It has the power of coagulating and then dissolving milk casein. Galactase resembles pepsin, but appears to be much slower in its action (references No. 1, p. 161; No. 13, p. 77; and No. 14, p. 157).

EXPERIMENT AND PRACTICE WORK, SIXTH LECTURE.

Time required for experiments.—Four hours or more can be advantageously given to the following experiments:

Apparatus required.—(1) Monrad's or Marschall's rennet test; (2) rennet extract; (3) aseptic scale pepsin, 1-3000; (4) dilute sulphuric acid; (5) sodium carbonate; (6) salt; (7) calcium chlorid, and (8) thermometer.

1. *Effect of acids on rennet coagulation of milk.*—Take 2 or 3 quarts of milk, test acidity (see Lecture 5, paragraph 2), then determine rapidity of coagulation by the rennet test (Lecture 5, paragraph 3). Record results. To 1 pint of the remaining milk add 10 cubic centimeters of dilute sulphuric acid made by adding 1 cubic centimeter of sulphuric acid, such as is used in Babcock test, to 100 cubic centimeters of water. Test acidity of milk again and make rennet test again. Increase amount of acid in the milk by adding 20 cubic centimeters more. Again test acidity and make rennet test. Compare results. Then add 20 cubic centimeters more of dilute acid and make acid and rennet tests again.

2. *Effect of alkali on coagulation of milk by rennet.*—Add to 1 pint of milk 1 gram of sodium carbonate and add rennet in usual amount. If it coagulates, note the time required.

3. *Effect of letting milk stand on rennet coagulation.*—Make acid and rennet tests of a sample of milk. Put milk in warm place (80° to 90° F.) and repeat acid and rennet tests at intervals of a half hour for four or five hours or more. Keep careful record of all tests.

4. *Effect of temperature on rennet coagulation.*—Make rennet test of some milk at 84° F. Then make tests at following temperatures and note results: 60° F., 70° F., 75° F., 80° F., 90° F., 100° F., 110° F., 120° F., and 140° F.

5. *Effect of heat on coagulating power of rennet.*—Heat some rennet extract to 140° F. for fifteen minutes and then test its coagulating power.

6. *Effect of amount of rennet upon coagulation of milk.*—Perform the rennet test upon portions of the same milk, using (a) 5, (b) 10, (c) 15, (d) 20, and (e) 25 cubic centimeters of rennet extract. Note and compare the results.

7. *Effect of dilution by water upon coagulating power of rennet.*—Make a rennet test of some milk. Dilute portions of this milk as follows: (a) One part of water and four parts of milk; (b) one part of water and three parts of milk; (c) one part of water and two parts of milk; and (d) one part of water and one part of milk. Make rennet test of each of diluted samples and compare results.

8. *Effect of salt upon coagulating power of rennet.*—Make rennet test of samples of milk. Then to the same milk add salt in amounts equal to 1, 2, 3, 4, and 5 per cent of the milk by weight. Make rennet test of each of these salted samples and compare results. Try similar experiments with common borax.

9. *Effect of heating milk upon rennet coagulation.*—Make rennet test of some milk. Heat one portion of milk at 160° F. for twenty minutes and another portion to boiling for fifteen minutes. Then make rennet tests again. To some of the boiled milk add a few drops of dilute acid and repeat the rennet test.

10. *Effect of soluble calcium salts on action of rennet.*—Make rennet test of a sample of milk. Add 1 cubic centimeter of a 10 per cent solution of calcium chlorid to the milk and repeat.

11. *Effect of calcium salts on rennet coagulation of heated milk.*—Heat a portion of same milk used in experiment 10 to boiling for ten or fifteen minutes. Cool and make rennet test. To another portion add dilute calcium chlorid and make rennet test.

12. *Variation of rennet coagulation in milk of different cows.*—Make rennet test on separate milk of each cow of some available herd.

13. *Compare rennet extract with 1-3000 aseptic scale pepsin*, using the pepsin at the rate of one-half gram per 100 pounds of milk (reference No. 8, pp. 34, 53).

SEVENTH LECTURE.

PRELIMINARY STEPS IN MAKING CHEDDAR CHEESE.

Outline of different steps of operation of cheese making.

1. System of keeping records of the operations of cheese making.
2. First care of milk at the factory.
3. Ripening the milk.
4. Adding color.
5. Coagulating the milk by rennet ("setting" the milk).
6. Cutting the curd.
7. Heating the curd.
8. Removing the whey from the curd.
9. Cheddaring the curd.
10. Milling the curd
11. Salting and pressing curd.
12. Curing cheese.

1. *System of keeping records of the operations of cheese making.*—It is desirable for all cheese makers to keep daily records of the details of

their work for constant reference, and it is absolutely necessary that students keep such records faithfully from the start. Below we give the details of such a record:

	Date.	, 190 .
1. Vat used (number of vat).		
2. Condition of milk (tainted, clean, etc.).		
3. Amount of milk in vat.....		pounds.
4. Fat in milk.....		per cent.
5. Ripeness of milk by—		
1. Monrad rennet test.....		seconds.
2. Marschall rennet test.....		spaces.
3. Acid test.....		per cent of acid.
6. Kind of starter used.		
7. Amount of starter used.....		pounds.
8. Time when starter was added.....	a. m.	p. m.
9. Temperature of milk when rennet was added.....		degrees F.
10. Ripeness of milk when rennet was added—		
1. By rennet test.....		seconds or spaces.
2. By acid test.....		per cent.
11. Time when rennet was added.....	a. m.	p. m.
12. Amount of rennet (or pepsin) used.....		ounces or grams.
13. Amount of rennet (or pepsin) used per 1,000 pounds of milk....		ounces or grams.
14. Time when curd was cut.....	a. m.	p. m.
15. Time in coagulating.....		minutes.
16. Condition of curd when cut (hard, soft, etc.)		
17. Time when heating began.....	a. m.	p. m.
18. Acid test of whey when heating began.....		per cent.
19. Temperature to which milk was heated after cutting, etc.....		degrees F.
20. Time at which temperature was reached.....	a. m.	p. m.
21. Test when whey was drawn—		
1. By hot-iron test.....		inches.
2. By acid test.....		per cent.
22. Time at which whey was drawn.....	a. m.	p. m.
23. Time from cutting curd to drawing whey.....	a. m.	p. m.
24. Amount of fat in whey.....		per cent.
25. Condition of curd (sweet, tainted, solid, gassy, floating, etc.).		
26. Time when curd was ground.....	a. m.	p. m.
27. Length of string on hot iron when curd was ground.....		inches.
28. Acid test of whey drippings when curd was ground.....		per cent.
29. Time when curd was salted.....	a. m.	p. m.
30. Acid test of whey running from curd just before salting.....		per cent.
31. Amount of salt used for 1,000 pounds of milk.....		pounds.
32. Time when curd was put in press.....	a. m.	p. m.
33. Temperature of curd when put in press.....		degrees F.
34. Kind of cheese made.		
35. Number of cheeses made.		
36. Time when cheese was dressed.....	a. m.	p. m.
37. Time when cheese was pressed.....	a. m.	p. m.
38. Weight of green cheese.....		pounds.
39. Average amount of milk per pound of cheese.....		pounds.
40. Amount of cheese from 100 pounds of milk.....		pounds.
41. Amount of cheese made from 1 pound of milk fat.....		pounds.

Special remarks.—(Include here any deviations from the usual modes of procedure not included in the foregoing list.)

2. *First care of milk at the factory.*—While the milk is accumulating in the vat, it should be stirred frequently up to time of setting in order to keep the cream from separating. When the vat is full enough, the amount of milk present being figured, the acidity of the milk is determined or a rennet test made. If, as usually happens, the milk is sweet, heat to 84° to 86° F. and ripen (reference No. 8, p. 49).

3. *Ripening milk.*—(References No. 3, p. 68, and No. 8, p. 49.) This consists in the formation of a certain amount of lactic acid. Its object is to control more completely the operations of cheese making. Lactic acid may be formed by allowing milk to stand a while at a temperature of 84° to 86° F. When lactic-acid bacteria are not present abundantly or are kept back in growth by injurious organisms, it is necessary to use a "starter."

4. *Preparation of starter.*—(References No. 3, p. 43, and No. 8, p. 50.) A starter is a material containing large numbers of lactic-acid organisms added to milk or cream for the purpose of causing lactic fermentation. Starters are of two kinds—(1) natural and (2) pure culture (references No. 8, p. 51, and No. 9, pp. 197, 199.) A natural starter may be prepared as follows: Milk of the best possible character, taken under precautions necessary to insure cleanliness, is heated to 90° F. and then kept at 65° to 70° F. In twenty-four hours this is ready for use. Some of this starter may be used in preparing a starter for the following day, putting a little into some skim milk that has been heated to 180° F. for thirty minutes and then cooled to 70° F. and allowed to stand twenty-four hours. The starter may thus be propagated from day to day. A new starter should be prepared as soon as any unfavorable quality is noticed. Pure-culture starters are special preparations consisting of certain selected organisms known to be adapted to forming lactic acid. Several such are on the market and give good results (reference No. 8, p. 51). Starters should not be prepared from the milk mixed in the vat or from whey (reference No. 8, p. 48).

5. *Use of starter in cheese making.*—In using a starter reject the upper portion and pass the rest into the milk through a fine strainer. The amount to be used depends upon the acidity or ripeness of the milk at the start, but will vary from 2 to 5 pounds for each 100 pounds of milk (reference No. 3, p. 69). Experience must serve as a guide to some extent.

6. *How to ascertain the proper degree of ripeness.*—Since ripeness in milk is the same as acidity, the ripeness can be measured (1) by determining the acidity, as described in Lecture 5, paragraph 19, or (2) by making a rennet test. The general aim is to have such an amount of acid formed when the rennet is added that the curd will remain in the whey not more than two and three-quarters to three hours. This result is usually accomplished when the acid test shows 0.19 to 0.21

per cent of acid or when the milk coagulates by the Monrad test in forty-five to sixty seconds or by the Marschall test in two and one-half spaces. Milk containing as much as 0.2 per cent of lactic acid when delivered at the factory is overripe and liable to cause trouble (references No. 3, p. 69, and No. 8, p. 48).

7. *Adding color.*—When coloring matter is used, it should be added just before the rennet is, being diluted before addition and thoroughly mixed into the mass of milk (reference No. 8, p. 52). The amount used depends upon the special demand of the market.

8. *Preparation and addition of rennet.*—Adding rennet is commonly known as “setting milk with rennet.” The milk is heated gradually to 84° to 86° F., with constant stirring and tested for ripeness. If ripe enough, rennet is added at once. If not ripe enough, it is allowed to stand until it gives the right test, a starter being used or not, as circumstances require. When the milk is ripe enough, the rennet extract is added. In this connection three points must be considered—(1) temperature of milk, (2) amount of rennet added, and (3) method of adding extract.

(a) *Temperature of milk.* Different makers use for setting milk different temperatures varying from 82° to 86° F. The higher temperature saves time by hastening ripening, especially when no starter is used. At temperatures much above 86° F. the curd hardens too quickly to handle conveniently, and there is danger later of loss of fat (references No. 3, p. 70, and No. 8, p. 52).

(b) *Amount of rennet extract to use.* This will depend on the strength of the extract, other things being equal. Use enough to coagulate the milk in fifteen to twenty minutes for a quick-curing cheese and in thirty to forty minutes for a slow-curing cheese. The extract commonly used is added at the rate of 2½ to 5 ounces for 1,000 pounds of milk.

(c) *Method of adding rennet extract.* Before being added to milk the rennet should be diluted with twenty to forty times its volume of water to prevent uneven action in the milk. The milk should be thoroughly stirred just before the rennet is added. Then after the addition of the rennet the milk is at once stirred again gently, but thoroughly, and continued for some minutes. Then the surface is stirred quietly to keep cream from rising, but is stopped before there is any sign of coagulation. The surface is then covered with cloth to hold temperature and the milk kept undisturbed until coagulation is complete (references No. 3, p. 71, and No. 8, p. 53).

[Suggestions to lecturer: Each student should receive special practice under supervision in each of the manipulations described. Practice in ripening milk can at first be obtained with small amounts of milk. The preparation and use of starters must receive most careful attention in practice. In working with larger quantities of milk the

lecturer can direct and supervise the work closely and gradually leave the students a greater degree of independence as they show a proper comprehension and power of manipulation.]

9. *Use of pepsin in place of rennet in cheese making.*—(Reference No. 8, p. 53.) Rennet extracts are practically impure and dilute forms of pepsin. In place of rennet extract one can use pepsin at the rate of 5 grams for 1,000 pounds of milk. The pepsin is dissolved in any convenient amount of water before addition to milk. Only *scale pepsin* should be used. The pepsin solution should be made up daily in just the amount needed for the day.

EXPERIMENT AND PRACTICE WORK, SEVENTH LECTURE.

Time required.—Two hours or more can be easily given to the work outlined below.

Apparatus, etc., required.—(1) Pails, arrangements for heating, small vats, thermometers; (2) rennet extract, pepsin; (3) skim milk, 10 to 20 pounds or more for each worker; (4) whole milk, 100 pounds or more, and (5) rennet test and acid test.

1. *Preparation of starter.*—Prepare starter according to directions given.

2. Ripen 10 or 20 pounds of milk in a pail with and without using a starter. Apply rennet test and also determine degree of acidity. After the milk has ripened properly add rennet.

Compare pepsin and rennet.

When some familiarity has been acquired in handling small amounts of milk, then perform the work with 100 pounds or more of skim milk and later with whole milk.

EIGHTH LECTURE.

CUTTING AND HEATING CURD.

1. *Purpose of cutting curd.*—The object of cutting curd is to allow the whey to go out of the paracasein. This is more rapid and complete in proportion as the pieces of curd are smaller (reference No. 3, p. 71).

2. *When to cut curd.*—Curd cut too soft results in large losses of fat and smaller yield of cheese. Curd that is too hard before cutting loses whey less easily and results in poor quality of cheese. Hence curd must be cut at right stage of hardness. The stage for cutting is ascertained in this way: The end of index finger is inserted obliquely into curd half an inch or more and then slowly raised to surface. If the curd breaks apart with a clean fracture without leaving small bits of curd on the finger and if the whey in the broken surface is clear and not milky, the curd is ready to cut (references No. 3, p. 72, and No. 8, p. 53).

3. *How to cut curd*.—In cutting curd uniformity in size of pieces of curd must be the object. Two knives of special design are used in cutting curd. One is the horizontal knife with numerous parallel blades; the other, the perpendicular. Makers differ somewhat in their way of using these knives. The following directions should be followed: (1) Use horizontal knife first. (2) Insert carefully into curd at one end of vat. (3) Do not jam or smash the curd in inserting knife. (4) Move the horizontal knife quietly and firmly from end to end of the vat until it has passed through the whole mass of curd. (5) Then use perpendicular knife at once. (6) Cut not only lengthwise the vat, but also crosswise. (7) Toward the end of cutting move the knife somewhat more rapidly. In overripe milk the curd should be cut into smaller pieces. The fineness is governed largely by the number of times the knives pass through the curd (reference No. 8, p. 55).

4. *Effect of fineness or coarseness of curd*.—Cutting curd fine has the effect of releasing the whey more rapidly and completely and results in a cheese containing less moisture. Coarse cutting causes the slower escape of whey and produces cheese with a higher moisture content.

5. *Stirring curd after cutting*.—The curd if allowed will settle to the bottom of the vat after cutting and mass together again, thus preventing the proper escape of the whey. To prevent this massing the curd must be kept in motion, very gentle at first, while the curd is soft. The curd must be kept from settling in the corners of the vat or sticking to sides. The whey should be clear and quite free from particles of floating curd (references No. 3, p. 73, and No. 8, p. 57). The curd contracts and hardens on surface during stirring, so that pieces do not stick together so easily. The hardening retards escape of whey, and heat must be used to keep whey from going out of curd.

6. *When to apply heat*.—The heating or "cooking," improperly so called, should begin as soon as the pieces of curd contract and harden on the surface. The cause of the shrinkage is probably due in part to the action of lactic acid upon the calcium paracasein of the curd, the calcium being combined with the lactic acid in forming free paracasein, a compound that has the property of contracting. Heat favors the formation of acid, and its action upon the calcium paracasein of the curd. The heat should be applied gradually and the stirring continued constantly. Under normal conditions the heat is applied so as to raise the temperature of the curd and whey 1° F. in five minutes and rarely more than 2°. The heating should be somewhat slower up to 90° F. than above that point, because the shrinking of curd and expulsion of whey take place less rapidly below than above 90° F. The heating should be carried up to 98° F. The curd becomes less tender as the temperature increases and toward the last can be stirred very vigorously without harm. When 98° F. has been reached, the

curd is allowed to settle on the bottom of the vat with only an occasional stirring until a certain amount of free paracasein is formed by the action of more lactic acid (references No. 3, p. 73, and No. 8, p. 57). There are special forms of apparatus that may be used in stirring curd (reference book No. 8, p. 59).

7. *Acidity of whey in regulating heating.*—If the first whey contains about 0.11 per cent of acid, the acid will form slowly and the curd should be heated more gradually. If the whey contains 0.13 or 0.14 per cent of acid, the curd can be heated more rapidly.

[Suggestions to lecturer: In the first stages of cheese making there is needed great care in developing an acute sense of observation, not only of sight but of touch. These can be acquired only by actual experience under the guidance of a trained teacher. In the condition of curd at time of cutting and in the gradual changes of pieces of curd from very soft to tough condition there is opportunity for the very closest training in observation.]

EXPERIMENT AND PRACTICE WORK, EIGHTH LECTURE.

Time required.—Two to four hours should be given to the work.

Apparatus required.—The apparatus is the same as for the preceding lecture and in addition curd knives.

1. Go through operation of cheese making from start either with 10 or 20 pounds of milk in a pail or with 100 pounds or more in a small vat. Make special study of indications that tell when to cut curd.

2. The use of curd knives can be learned only by use in a vat. Practice using the knives carefully according to directions of instructor.

3. Stir curd after cutting with care, and constantly study the appearance of the curd in order to learn when to apply heat.

4. Apply heat according to directions, watching the changes that take place in the curd.

NINTH LECTURE.

REMOVING WHEY FROM CURD AND CHEDDARING THE CURD.

1. *When to remove whey from curd.*—The whey should be removed from curd when lactic acid has caused the formation of certain amount of free paracasein or when there is "enough acid on the curd," as the cheese maker commonly says (reference No. 3, p. 73, or No. 8, p. 61). The whey should be removed very promptly when the time comes and the curd thoroughly drained.

2. *How to ascertain when there is acid enough.*—Several indications show when the whey should be removed from the curd. (1) The pieces of curd should be contracted to less than one-half their original size. (2) They should be firm and rubber like, so that when a mass of curd is pressed between the hands and then suddenly freed from pressure the pieces should fall apart at once and show no tendency to

stick together. (3) The curd should show strings one-eighth of an inch long on the hot iron by the test described in Lecture 5, paragraph 5. (4) Instead of the hot-iron test the amount of acid in the whey may be used, which should be about 0.01 per cent less than at the time of setting. Thus, if the acidity of the milk was 0.19 per cent at the time of setting, the acidity of the whey should be about 0.18 per cent when the whey is removed from the curd.

3. *Changes caused in curd by formation of acid.*—(Reference book No. 13, p. 36.) The curd formed by rennet from milk is an impure form of calcium (lime) paracasein. When lactic acid is formed in the curd and whey it gradually unites with the calcium, forming free (not combined with calcium) paracasein and calcium lactate. It is this free paracasein that draws out in silky threads on a hot iron. It is free paracasein also that imparts to cheese curd its peculiar plastic or "matting" properties. The formation of free paracasein is the main object of forming acid in cheese making.

4. *Effect of excessive and incomplete heating ("cooking").*—A curd that is heated too high or too long produces a cheese with too little moisture, resulting in a "corky" texture. Heating at too low a temperature or for an insufficient length of time results in producing cheese containing too much moisture and showing a pasty, soft body. Such cheese sours easily.

5. *Cheddaring the curd.*—This operation is the distinctive feature of the cheddar method of cheese making. It consists, essentially, in allowing the curd to mat or pack together in solid chunks after removal of whey. The operation may take place (1) directly on the bottom of the vat or (2) on curd racks placed in the bottom of the vat, or (3) it may be removed to a curd sink (reference No. 3, p. 74, or No. 8, p. 67).

6. *Matting curd on vat bottom.*—After the whey is drawn off the curd is piled up along the two sides of the vat with an open channel between to facilitate the running off of the whey that drains from the curd. When pieces of curd have matted together, forming a solid mass, it is cut into blocks about 8 by 8 by 12 inches, which are turned over. After some draining the blocks are piled two deep, each time the upper part being turned down. Later the blocks are piled in deeper piles. The repiling is repeated again and again, always exposing to the air the portions that were turned inside on the previous piling in order to keep the heat uniform through the mass (references No. 3, p. 74, and No. 8, p. 64). Curd racks and curd sinks are frequently convenient in facilitating draining (references No. 3, p. 75, and No. 8, p. 64).

7. *Effects of cheddaring curd.*—Cheddaring curd effects two results: Expulsion and draining of whey from curd, and (2) formation of free paracasein as a result of the union of lactic acid with the calcium

of calcium paracasein (reference No. 1, p. 36). As a result of the changing of most of the calcium paracasein into uncombined paracasein the physical condition of the curd changes from a tough, rubber-like consistency with a high water content to a mass having a smooth, velvety appearance and feeling, and a softer, somewhat plastic consistency. The texture also changes so that the curd acquires a peculiar fibrous condition or grain, tearing off somewhat like the cooked meat of the chicken's breast. Along with these changes the curd forms longer strings on a hot iron, usually an inch or more after the cheddaring has continued some time.

8. *Influence of cheddaring upon quality of cheese.*—Extended piling of curd tends to make a quick-curing, soft cheese. If a slow-curing cheese is desired, the curd should be piled little or none at all, the blocks being simply turned over and over in a single layer. Curd from very ripe milk should be piled little (reference No. 8, p. 69).

9. *When the cheddaring process is complete.*—The cheddaring process is regarded as complete when we have the following conditions: (1) The curd forms strings on hot iron an inch or more in length. (2) The whey running from the curd shows an acidity of 0.7 to 0.8 per cent. (3) The curd should be velvety in appearance and feeling and tear apart like the breast meat of a chicken.

EXPERIMENT AND PRACTICE WORK, NINTH LECTURE.

Time required.—Since it is necessary to begin with the operation of cheese making each day, additional time will be required each day, but this will serve to review preceding stages.

Apparatus, etc., required.—Same as before. Small amounts of milk can be used in pails or a larger amount in a vat. The instructor will have to be governed by circumstances as to the detailed methods he employs.

1. Start in operation of cheese making and make special study of indications that tell when to remove curd, such as the appearance and feeling of the curd, test on hot iron, and acidity of whey. Apply all these tests carefully.

2. At proper time remove whey and proceed to the operation of cheddaring the curd. Study with care the changes that the curd goes through.

3. Make various tests for completion of process, such as hot iron, acidity of whey, and texture and appearance of curd.

TENTH LECTURE.

MILLING, SALTING, AND PRESSING CURD.

1. *Milling curd.*—(References No. 3, p. 76, and No. 8, p. 69.) When the cheddaring process is complete as determined by the tests given in the last paragraph of the preceding lecture the curd is ready

for milling. The time for milling should come about halfway between removing the whey and salting the curd. By this process the curd is cut into small pieces in order to salt it more uniformly and handle it more easily. Several machines are sold for this purpose. The best machines cut the curd into pieces of uniform size without tearing it.

2. *Treatment of curd after milling.*—After milling, the curd is piled up in order to flatten out the pin holes and stirred enough to keep it from matting together. The softening of the curd, which is the result of the formation of more uncombined paracasein, continues after milling as the result of further formation of lactic acid. The curd should be kept warm all the time (references No. 3, p. 76, and No. 8, p. 77).

3. *When to salt curd.*—The curd is ready for salting when (1) the hot-iron test shows strings 2 inches long, or (2) the whey running directly from the curd shows an acidity of 1 per cent in normal cases or 1.1 to 1.2 per cent in case of gassy or weak-bodied curds.

4. *Amount and kind of salt to use.*—The amount of salt used is usually at the rate of 2½ to 3 pounds for 1,000 pounds of milk. A moist curd should be salted more. A salt of fairly coarse grain is preferable, because it dissolves more slowly and penetrates the curd more fully. When the salt is added, the curd is spread out thin, cooled to 90° F. Then the salt is mixed evenly through the curd and the curd stirred until the salt dissolves completely.

5. *Effects of salting.*—While salt is added for the sake of flavor, it produces other effects, such as (1) aiding in removing whey, (2) hardening the curd, checking or retarding the formation of lactic acid. An unsalted cheese cures more rapidly and is apt to develop a better flavor, the intensity increasing with increase of curing temperature. Excessive salting makes a cheese mealy, because too dry, and cures slowly (reference No. 16, p. 157). Much of the salt added passes into the whey. Green cheese normally salted contains 0.6 to 1 per cent of salt, and this increases somewhat in the cured cheese through loss of moisture (reference No. 16, p. 147).

6. *Temperature of curd when put in press.*—Before pressing, the curd should be cooled to a temperature between 78° and 84° F. If pressed at higher temperatures, fat is lost and the pieces of curd do not stick together perfectly. If pressed at lower temperatures, the pieces fail to form a solid mass by cementing properly (reference No. 3, p. 76, or No. 8, p. 81).

7. *Object of pressing curd.*—The main object of pressing curd is to give the cheese a definite form for market and not alone to squeeze out whey, which should be removed mostly while the curd is in the vat.

8. *Preparing hoop for receiving curd.*—A round cap cloth of the size of the hoop is placed at the bottom and soaked in hot water. The bandage is then placed in the hoop, turning the edge in evenly about an inch and a half on the bottom. Curd is then placed in the hoop,

using about the same amount of curd in each hoop, but being careful not to fill hoop too full (reference No. 8, p. 83). The top cap cloth is then put on and the fibrous ring placed about edge and then the follower on top.

9. *Pressing curd*.—When the curd is put in press in normal condition, a moderate pressure will cause the pieces of curd to cement together in a smooth solid mass. The pressure should be uniform and continuous for twenty-four hours. With a screw press the pressure is applied gradually at first, full pressure reached in about fifteen minutes, and is tightened as fast as the screws become loose, especially during the first hour (reference No. 8, p. 84).

10. *Dressing cheese*.—When the curd has been in press about one hour it is well compacted and is then taken out. The bandage is freed from wrinkles and trimmed evenly, so that it will come over the end of the cheese about an inch and a half. Put it in position and soak it with hot water; then wring out the cap in hot water and place it on the end of the cheese (reference No. 8, p. 85). Return to press and apply full pressure.

[The mechanical manipulations involved in preparing the hoop and dressing the cheese can be properly learned only from actual practice, and the foregoing outline must be filled in by the students under the fuller directions of the lecturer.]

For a description of presses, bandages, hoops, etc., see reference No. 8, pp. 81–85.

11. *Troubles common in cheese making*.—Temperature conditions during cheese making favor growth of many kinds of bacteria, and sometimes undesirable forms prevail, producing abnormal behavior in curd and defective cheese. Two of the most familiar conditions are gas-forming fermentations and overripe milk.

12. *Gas-forming fermentations*.—Some fermentations produce gas in the curd, causing it to swell, filling it with small holes and making it very spongy. The result of such conditions is a “floating” or “gassy” curd. This condition is due to lack of cleanliness on the part of one or more patrons. Such milk can be detected by the curd test (see Lecture 5, paragraph 4). When suspected, the results of these fermentations can be prevented or lessened by abundant use of a starter, developing in the curd abundance of lactic acid, which is more or less poisonous to the gas-forming bacteria. The milk is well ripened before adding rennet, and the curd heated somewhat more rapidly than usual and from 2° to 6° higher. The escape of gas from curd is favored by keeping warm and frequent repiling. Gas fermentations often produce offensive smells in the curd, and these may be largely washed out by drenching the curd with warm water (105° F.). However, it is difficult to make perfect cheese without some loss of yield from such milk. The ideal method is prevention by cleanliness (references No. 3, p. 77, and No. 8, p. 66).

13. *Overripe milk*.—In hot weather milk may be on the verge of souring when ready to be made into cheese. Under such conditions the changes occur more rapidly than usual; the curd “works too fast.” The whey does not escape fast enough. This may be helped by stirring curd constantly and thoroughly after removing whey. No starter should be used in an overripe milk; more rennet should be added to the milk and at a lower temperature. After cutting, the curd is stirred until the whey separates well before raising temperature (references No. 3, p. 78, and No. 8, p. 58).

EXPERIMENT AND PRACTICE WORK, TENTH LECTURE.

Time required.—The work at this point carries one through the whole operation of cheese making and will use five to seven hours or more a day.

Apparatus, etc., required.—Same as before, with curd mill, salt, cheese press, bandage, etc.

Start operations of cheese making from beginning. Mill the curd when the indications are right. Then pile and stir occasionally, keeping it warm all the time. Study the changes in curd.

Salt the curd at time shown by hot-iron test and by acid test.

Observe temperature when curd is put to press.

The instructor must give personal illustrations of method of preparing press, pressing, dressing cheese, etc.

After the details of the entire operation of cheese making have been fairly well mastered, then the students can undertake such of the following experiments as they may have time for:

(1) Make cheese from 100 pounds or more each of (a) milk skimmed by separator, (b) normal milk containing 3 to 3.5 per cent of fat, and (c) normal milk containing 4 to 4.5 per cent of fat. Note the following points: (1) The weight of cheese in each case, (2) the per cent of fat in whey in the case of b and c, and (3) the commercial quality of the cheese when one and two months old.

(2) Make cheese from 100 pounds or more of normal milk and from the same amount of milk to which has been added 25 per cent of water. Compare results in yield, loss of fat in whey, etc.

(3) Make cheese from two portions of the same milk. Run one portion in a normal manner and the other portion in the same way, except to stir the milk after it has begun to coagulate with rennet. Notice the appearance of the whey in both cases, and also the per cent of fat in whey and the yield of cheese.

(4) Compare results in respect to per cent of fat in whey and yield of cheese when curd is cut (a) hard, (b) medium, (c) soft, (d) coarse, (e) fine, (f) carefully, (g) carelessly.

(5) Compare results in respect to per cent of fat in whey, yield and quality of cheese when (a) the curd is heated (“cooked”) too quickly, (b) too slowly, (c) too high, (d) too low.

(6) Compare results in respect to per cent of fat in whey, yield and quality of cheese when (a) the curd is put to press too warm, (b) too cold.

(7) Make into cheese milk containing 0.2 to 0.25 per cent of acid and study the behavior of the curd, the per cent of fat in whey, and the quality and yield of cheese.

(8) Make cheese with use of rennet at the rate of 3, 6, and 9 ounces per 1,000 pounds of milk. Compare results in working, in behavior of curd, and in quality of cheese at thirty and sixty days.

(9) Salt cheese at rate of 2, 4, and 6 pounds of salt per 1,000 pounds of milk. Note the yield of cheese and the quality at thirty, sixty, and ninety days.

(10) Make cheese from 100 pounds or more of (a) normal milk containing 3.5 to 4.5 per cent of fat and (b) from skim milk made from the same amount of the same milk after it has had its fat removed by being run through a separator. Compare the yields of cheese.

ELEVENTH LECTURE.

CARE OF CHEESE AFTER MANUFACTURE.

Importance of care of cheese after being made has been overlooked. The best made cheese can be easily ruined by lack of care after removing from press. Few cheese factories have proper facilities for curing cheese in the best way. Under the old system much emphasis was placed on greasing cheese, using caps, and making great efforts to prevent mold, but little effort was made to reduce loss of moisture.

1. *Changes caused by curing cheese.*—Cheese must have age before it is salable for consumption. Several different changes take place during curing period, among which are (1) loss of moisture and (2) changes in paracasein.

2. *Loss of moisture in curing cheese.*—(Reference No. 17, p. 281.) Cheese begins to lose weight as soon as it is taken from press, and the loss continues some months. The rapidity and extent of loss of moisture vary with several conditions, such as (1) the percentage of moisture present in green cheese, (2) texture of cheese, (3) size and shape of cheese, (4) temperature of curing room, (5) moisture in air of curing room. The more moist a cheese when first made the more rapidly it loses moisture. Cheese with spongy texture loses moisture more rapidly than cheese with perfect texture. Large cheeses lose moisture less rapidly in proportion to their weight than smaller cheeses. "Flats" lose weight more rapidly than cheeses of the same diameter and twice the height. The higher the temperature of the curing room the greater the loss of moisture. The greater the moisture in the air of the curing room the smaller is the loss of weight.

3. *Changes in paracasein.*—In freshly coagulated cheese curd the calcium casein of milk is changed to calcium paracasein, which, under

the action of lactic acid, is changed during the process of cheese making into free paracasein (not combined with calcium). Fresh cheese, aside from the fat and moisture, consists largely of this uncombined paracasein. This compound undergoes the changes in ripening which profoundly affect the whole character of the cheese. Green cheese is tough, somewhat rubber-like, not appreciably soluble on the tongue, difficult of digestion, and lacking in flavor. In the course of ripening it becomes softer, more easily digestible, and acquires characteristic flavors. The exact causes of these changes are not known fully, but they are due in part to rennet, in part to galactase, and in part to bacterial action, either direct or through their enzymes. Flavor is not formed by either rennet or galactase (reference No. 3, p. 80). These changes are influenced in extent and rapidity by temperature, moisture, amount of rennet and salt used in making cheese, and amount of acid present (reference No. 16, p. 156).

4. *Influence of temperature upon quality of cheese.*—Cheese cures more quickly at higher temperatures, but at the expense of flavor and texture. Cheese cured at 75° F. or above loses fat by leakage. Cheddar cheese cured above 60° F. does not give the best quality. Cheese cures more slowly at lower temperatures but the product is superior in quality. Also less moisture is lost at lower temperatures. Best results are secured by curing cheese below 40° F. for a period of six months or more (references No. 18, p. 54, and No. 19, p. 110).

5. *Covering cheese with paraffin.*—Loss of moisture in cheese can be largely prevented by coating the cheese with a thin layer of paraffin without injuring the quality (reference No. 18, p. 82, or No. 19, p. 111). At higher temperatures the saving is greater and the quality is better than in cheese not so treated. Another distinct advantage of using paraffin is that it prevents cheese becoming moldy. Conveniences for coating cheese with paraffin can be obtained from dairy-supply houses. The cheese should be allowed to dry out well on the surface and then dipped in melted paraffin that is at a temperature of 150° to 200° F., using paraffin that has a melting point not above 120° F. From three days to a week should be enough to dry out the surface of the cheese before coating.

6. *Moisture in air of curing rooms.*—(Reference No. 3, p. 81, or No. 8, p. 100.) The relative amount of moisture in the air can be determined by a hygrometer. For curing Cheddar cheese the moisture should be 65 to 75 per cent of saturation.

7. *Control of moisture and temperature in curing rooms.*—If a cheese maker cures his own cheese properly he should have a special curing room, properly made and equipped. The curing room should be on the coolest side of the building with the least possible outside exposure. Details for construction are given in Wisconsin Experiment Station Bulletin 70. The control of moisture and temperature are secured

through (1) ventilation by air forced through horizontal subearth ducts or deep vertical subearth wells and ducts; (2) ventilation over ice; or (3) evaporation of water (reference No. 20 or No. 3, p. 81).

8. *Method of procedure in the absence of curing rooms.*—Where it is impossible to have proper curing rooms the best results can be realized by coating the cheeses with paraffin and turning them over to the buyer at once, or the factory may arrange to place them in some convenient cold storage.

EXPERIMENT AND PRACTICE WORK, ELEVENTH LECTURE.

In a course of cheese instruction like the one contemplated by this course of study it will hardly be practicable to undertake any experiment or practice work in cheese making. The most that can be done is for the lecturer to arrange to have on hand for illustration cheeses that have been cured at different temperatures and with and without paraffin covering.

TWELFTH LECTURE.

COMMERCIAL QUALITIES OF CHEDDAR CHEESE AND METHODS OF JUDGING CHEESE.

1. *Qualities of cheese.*—Certain qualities of American Cheddar cheese have been adopted as a basis of the commercial value of one cheese as compared with another. The terms commonly used in expressing these qualities are the following: (1) Flavor, (2) body, (3) texture, (4) color, (5) general appearance, and (6) salt. The number of terms used varies in different market centers.

2. *Score cards.*—As a matter of convenience and uniformity, score cards are often used. The following is a typical illustration of a score card:

Cheese judging numerical and descriptive score card.

Score for cheese (or sample) marked —.

NUMERICAL SCORE.

	Perfection.	Score.
	<i>Points.</i>	<i>Points.</i>
Flavor.....	45	
Texture.....	20	
Body.....	15	
Color.....	10	
Appearance and salt.....	10	
Total.....	100	

Date.....190 . Initials or number of judge.....

DESCRIPTIVE SCORE.

[Check qualities below as they apply to cheese examined.]

Flavor.	Texture.	Body.	Color.	Appearance.	Salt.
Perfect. Clean. High or quick. Low or flat. Too much acid. Too little acid. Sour. Sweet or fruity. Tainted. Weedy. Barnlike. Strong. Tallowy.	Perfect. Close. Loose or porous. Mechanical holes. Gas or pin holes. Swiss holes.	Perfect. Solid or firm. Smooth. Sulky. Waxy. Pasty or salvy. Stiff, corky, or curdy. Weak. Weedy. Gritty. Watery. Dry.	Perfect. Straight. Translucent. White specks. Streaked. Wavy. Mottled. Acid cut. Too high. Too light. Uncolored.	Perfect. Edges square. Kind smooth. Cracks. Light spots. Neat. Slovenly.	Perfect. Too little. Too much.

3. *Flavor of cheese.*—By flavor, as applied to cheese, we mean the odor of the cheese, or really odor and taste combined. The sense of smell is generally more sensitive in detecting most variations of flavor in cheese than taste. The flavor of cheese is ascertained by crushing a piece in the palm of the hand to warm it up slightly and is at once held under the nose.

(a) "Perfect" flavor in Cheddar cheese resembles that of first-class butter, with an added something of its own that can not be easily described. Cheese flavor is sometimes described as "nutty." Perfect cheese flavor is not strong and is free from all traces of an objectionable character. The taste should be mild and somewhat lasting, but not so sharp as to "bite" the tongue.

(b) "Clean" flavor is entirely free from objectionable smell.

(c) "High" or "quick" flavor is a delicate flavor that disappears quickly.

(d) "Low" or "flat" flavor indicates only traces or absence of flavor, or insipidity.

(e) "Too much acid" applies to flavor that smells somewhat sour, but does not taste sour.

(f) "Too little acid" applies to flavor that is rather mild and lacking in character.

(g) "Sour" cheese tastes sour when fresh, from containing too much whey.

(h) "Sweet" or "fruity" flavor is suggestive of pineapple odor and is somewhat sickish.

(i) "Tainted" flavor describes a variety of mildly or strongly offensive odors.

(j) "Weedy" flavor applies to flavor coming from food eaten by cow, such as leeks, ragweed, cabbage, etc.

(k) "Barnlike" flavor is self-descriptive, suggesting odor of manure.

(l) "Strong" flavor is very pronounced, but free from anything offensive; it is a good flavor strongly developed.

(m) "Tallowy" flavor resembles that of tallow.

4. *Texture of cheese*.—Texture, as applied to cheese, refers mainly to compactness. Commonly the body is considered as a part of texture, but the two qualities are easily distinct.

(a) "Perfect" texture in cheese is indicated when a cut surface of the inside of the cheese presents to the eye a solid, compact, continuous appearance, free from breaks, holes, and chunks. A plug drawn from a cheese of perfect texture should be smooth and not "fuzzy." When a plug is broken in two it should not crumble, but show a flaky appearance, termed a "flinty" break, resembling the surface of broken cast iron or broken flint.

(b) "Close" texture describes the appearance of a cut surface of cheese when free from all kinds of holes.

(c) "Loose" or "porous" texture is indicated by lack of compactness and solidity.

(d) "Mechanical holes" in cheese are irregular, open spaces caused by incomplete cementing together of the curd particles in the press.

(e) "Gas" or "pin holes" are small holes.

(f) "Swiss" holes are fairly large, round holes, such as are present in Emmenthaler cheese.

5. *Body of cheese*.—This term, used in connection with cheese, refers to the character of the substance or consistence of cheese. This quality is ascertained by pressing a piece of cheese between the thumb and fingers.

(a) "Perfect" body in a cheese is indicated when the cheese is solid, firm, and smooth in substance or consistence.

(b) "Solid" or "firm" bodied cheese shows a certain amount of resistance under pressure, somewhat like a piece of fat pork or cold butter.

(c) "Smooth" bodied cheese when pressed between the thumb and fingers feels smooth and velvet-like, as distinct from harsh, gritty, or mealy.

(d) "Silky" bodied cheese is smooth, but not over solid.

(e) "Waxy" bodied cheese is much the same as silky, but possessing more firmness or solidity.

(f) "Pasty" or "salvy" cheese is very soft, usually from an excess of moisture. It sticks to the fingers when pressed.

(g) "Stiff" or "corky" or "curdy" bodied cheese is hard, over-firm, and tough, and does not crush down readily when pressed in the hand.

(h) "Weak" bodied cheese is very soft, lacking in firmness, but not necessarily sticky.

(i) "Mealy" bodied cheese is cheese that breaks down in fine crumbs when pressed.

(j) "Gritty" bodied cheese feels harsh and gritty under pressure.

(k) "Watery" bodied cheese is excessively soft and pasty.

(l) "Dry" bodied cheese is generally very mealy or hard.

6. *Color of cheese*.—Whether artificially colored or not cheese may vary considerably in color.

(a) "Perfect" color in cheese is indicated by evenness of color throughout the mass of cheese. The cheese should be somewhat translucent.

(b) "Straight" color is even color throughout the entire mass of cheese.

(c) "Translucent" color applies to cheese which appears slightly translucent when the plug is held between the eye and the light.

(d) "White specks" is a term that explains itself. Such specks are a defect.

(e) "Streaked" color indicates that there are lighter portions of cheese in the form of streaks.

(f) "Wavy" color applies to lighter portions appearing in waves.

(g) "Mottled" color in cheese shows in light spots of fairly large size.

(h) "Acid cut" color is shown in cheese when considerable portions of the cheese have been made lighter in color by the presence of too much acid.

(i) "Too high" color is indicated by a reddish color, caused by using too much coloring matter. However, this question of color is a relative one, because the demand in different markets varies from uncolored to extremely high color.

(j) "Too light" color is usually used with reference to cheese that has been made uniformly dead white by the action of too much acid.

(k) "Uncolored" Cheddar cheese is not white, but of a light amber shade.

7. *Appearance of cheese*.—The term "appearance" refers to the general appearance of the cheese to the eye in respect to neatness and uniformity.

"Perfect." In a cheese of perfect appearance the curd must be smooth, even in color, free from cracks, and fairly hard. The bandage must be without wrinkle and neatly rounded over the edges about an inch and a half on each end of the cheese. The sides of the cheese should be straight and of uniform height all around.

The faults of appearance are as follows, the terms being self-descriptive: (1) Cracks, (2) light spots, (3) roughness in rind, (4) uneven edges, (5) wrinkles in bandage, (6) lack of uniformity in ends and in height, and (7) bulging out at sides or ends.

8. *Salt in cheese*.—The salt in cheese is "perfect" when just enough has been used to impart a sufficient taste to the cheese. "Too little" salt results in injury to flavor and texture, causing bitterness of flavor and porous texture. "Too much" salt results in a dry, mealy texture and imperfect flavor.

EXPERIMENT AND PRACTICE WORK, TWELFTH LECTURE.

Time required.—A half hour or less a day for several days will give more effective results in judging cheese than to devote more time continuously in one day.

Apparatus required.—A cheese trier.

1. The use of a cheese trier in taking a sample plug from a cheese should be learned first.

2. Have a score card ready. The examination of cheese for flavor is tried by direct smelling of plug and by warming some of the cheese in the hand. In each cheese examined let each one indicate what flavor or flavors he perceives and give it a numerical score. The examination for texture, body, color, appearance, and salt is carried on similarly, each one keeping a careful record describing each quality and also giving each a numerical value. After the examination of one cheese is completed it will be well for the instructor to go over the whole work in detail, pointing out any errors in judgment that may appear on the different score cards. Let every point be fully explained. Then pass on to another cheese. It is desirable, of course, to have as much variety as possible in the cheeses examined.

THIRTEENTH LECTURE.

THE MANUFACTURE OF COTTAGE CHEESE AND OF POTTED OR CLUB CHEESE.

Cottage or Dutch cheese is the product made by allowing milk to stand until it coagulates by ordinary souring, the curd being drained to allow the escape of much of the whey, after which it is salted, pressed into the form of balls, and is then ready for consumption.

1. *Material to use.*—Skim milk should be used. Whole milk loses too much of its fat in being made into cottage cheese.

2. *Preparation and use of starter.*—In making cottage cheese on a large scale considerable time can be saved by hastening the souring of the milk through the use of a starter prepared as described in Lecture 7, paragraphs 4 and 5. The character of the starter is of much importance. Impure starters may cause slimy fermentation, and from such curd the whey will not separate easily (reference No. 21, p. 34).

3. *Manufacture of cottage cheese without starter.*—The milk is kept at a temperature of 70° to 75° F. until well curdled, which will usually require twenty-four to forty-eight hours. The curdled mass is then broken by hand or cut by a curd knife and is heated gradually to 90° F. and is kept at this temperature until the whey appears clear. When the heat is so applied as to require thirty to forty minutes to reach 90° F., then the whey will usually separate clear in fifteen or twenty minutes. The whey is then removed and the curd is put into muslin bags or on racks and drained as long as whey runs. The curd is then

salted at the rate of 1 pound of salt for 100 pounds of curd, or to taste, shaped into pound or half-pound balls, and finally wrapped in oiled paper. For the finest quality of cheese, the curd before being made into balls should be mixed with thick cream, preferably ripened cream, at the rate of 1 ounce of cream for 1 pound of cheese (reference No. 21, p. 34).

4. *Manufacture of cottage cheese with use of starter.*—A good starter is added to milk at the rate of 2 or 3 pounds to 100 pounds of milk and thoroughly mixed through the mass of milk and then treated as described under the preceding paragraph 3 (reference No. 21, p. 35).

5. *Manufacture of cottage cheese with use of starter and rennet.*—The starter is added as described in paragraph 4 preceding, and about eight hours later rennet extract added at the rate of 1 ounce for 1,000 pounds of milk. The operation is completed as before described (reference No. 21, p. 35).

6. *Manufacture of cottage cheese by direct addition of hydrochloric acid.*—Have the milk at 70° to 80° F. Measure out pure hydrochloric acid, of specific gravity 1.20, at the rate of 10 ounces for 100 pounds of milk, dilute with ten times its bulk of water and add to milk gradually, stirring the milk constantly while the acid is being added. Continue the stirring until the curd separates completely, leaving a clear whey entirely free from milkiness. The whey is then run from the curd and the operation completed as before. In order to get the proper flavor, it will be necessary to mix with the curd some loppered milk or cream (reference No. 21, p. 35).

7. *Qualities of cottage cheese.*—(Reference No. 21, p. 36.) Flavor and texture are the most important qualities in cottage cheese. The flavor should be that of mildly soured milk or well-ripened cream. There should be an entire absence of all objectionable flavor, such as bitter taste, stable flavor, etc. If the cheese tastes too sour it is usually due to keeping too much whey in curd. The use of a starter is apt to insure the right kind of flavor. The texture of cottage cheese is largely dependent on the amount of moisture in the cheese. When the percentage of moisture is much below 70, the cheese is harsh, dry, and sawdust like. The right texture of cottage cheese is smooth and free from harshness.

8. *Yield of cottage cheese.*—From 100 pounds of milk one should obtain from 20 to 22 pounds of cheese. Variation in moisture makes much variation in yield (reference No. 21, p. 14).

9. *Composition of cottage cheese.*—Cottage cheese of the best texture contains 70 to 75 per cent of moisture. Curdling milk at too high a temperature and heating the curd too high or too long will make the cheese too dry. Cottage cheese contains about 3.5 to 4 per cent of milk sugar and 2 to 2.5 per cent of nitrogen, mostly in the form of casein lactate (reference No. 21, p. 14).

10. *Digestibility of cottage cheese.*—Cottage cheese is more readily digestible than fresh Cheddar cheese. Cottage cheese is ready for consumption as soon as made (reference No. 21, p. 33).

11. *The manufacture of potted or club cheese.*—This kind of cheese is on the market under various brand names, being put up in small jars. This is very easily prepared on a small scale. Take well-ripened Cheddar cheese of good quality, cut into small chunks and pass through a meat-grinding machine. To this ground cheese add 1 ounce of melted butter of good quality for each pound of cheese, and work it through the cheese mass until thoroughly incorporated. Pack this into small jars or jelly glasses, the inside surface of which has been smeared with melted butter. Cover the upper surface with a thin layer of melted butter and cover with paper. Keep in cool place until wanted for use.

EXPERIMENT AND PRACTICE WORK, THIRTEENTH LECTURE.

Time required.—The first day fifteen or twenty minutes will be sufficient to start the work. On the next day if the milk has fully curdled the operation can be completed in one or two hours.

Apparatus, etc., required.—Pails holding 25 pounds of milk and some means of controlling the temperature moderately are the chief utensils required besides a thermometer and some kind of a knife for cutting curd. Skim milk should be used, 20 pounds being enough for each student.

1. Make cottage cheese without starter, as described in paragraph 4.
2. Make cottage cheese with starter, preparing starter in the manner previously described. See paragraph 5.
3. Make cottage cheese with starter and rennet, according to paragraph 6.
4. In every case keep careful records of the work.

FOURTEENTH LECTURE.

METHODS OF PAYING FOR MILK FOR CHEESE MAKING.

1. *Weight-of-milk method.*—Until about 1894 the universal custom prevailed of paying for milk at cheese factories on the basis of the weight of milk furnished by each patron. This method is still common. It is based upon the false belief that all kinds of milk are of the same value for cheese making. The data presented in Lecture 2 show that this claim is entirely wrong. We know that milk varies greatly in composition, and the composition determines the cheese-making value.

2. *Difficulty of absolute fairness.*—In paying for milk at factories absolute fairness can be realized in every individual case only by knowing two points: (1) The amount of cheese that is made from each

milk and (2) the quality of such cheese. The exact amount of cheese produced can be ascertained only by a careful, direct determination of both fat and casein, the two solid constituents of milk that make cheese; but this is not practicable. The quality of cheese is quite dependent upon the per cent of fat in milk, assuming the milk to be clean in every way.

3. *Fat as a basis for fixing value of cheese milk.*—Fat in milk can be used as a fair basis in determining the value of milk for cheese making for two reasons: (1) The amount of cheese made from different milks is nearly in proportion to the amount of fat present in milk (see Lecture 2, paragraph 6). (2) Cheese made from milk rich in fat is higher in quality than cheese made from milk poorer in fat.

4. *Paying for milk on basis of weight of milk.*—When milk is paid for by weight alone, each patron receives money in proportion to the amount of milk taken; but each patron receives for 100 pounds of milk the same amount of money every other patron receives, without reference to the amount of cheese each patron's milk will produce.

5. *Paying for milk on basis of amount of fat in milk.*—To illustrate this method, we assume that two patrons furnish milk, one of which (A) contains 3 per cent of fat and the other (B) 4 per cent. The amount of cheese made from 100 pounds of milk A is 8.55 and that from milk B 10.65, or a total of 19.2 pounds, which sells at 10 cents a pound, or 192 cents. On the weight-of-milk basis each receives one-half, or 96 cents. On the basis of the fat in the milk one (A) receives three-sevenths, 82.3 cents, and the other (B) four-sevenths of the money, 109.7 cents.

6. *Comparison of two methods.*—The following table shows the result of paying for milk according to weight and according to fat content:

Paying for milk by weight and by fat content.

Name of patron.	Fat in 100 pounds of milk.	Cheese made from 100 pounds of milk.	Amount of money received when divided on fat basis.	Amount of money received when divided according to weight of milk.
	Pounds.	Pounds.	Cents.	Cents.
A.....	3	8.55	82.3	96
B.....	4	10.65	109.7	96

Notice the following facts: (1) By weight-of-milk method A receives same amount of money for 8.55 pounds of cheese that B does for 10.65 pounds. (2) A receives over 11 cents a pound for cheese, while B receives only 9 cents. (3) A receives 32 cents a pound for milk fat, while B receives only 24 cents. (4) A receives on 100 pounds of milk 13.7 cents, which really belongs to B. (5) One method makes no difference, while there really exists a difference of 27.4 cents in favor of B.

7. *Method of allowing for both casein and fat.*—In some factories, especially in Canada, the casein is taken into account in making dividends. This is done by adding 2 to the per cent of fat, on the assumption that all milks contain only 2 per cent of casein and that the figures thus obtained approximate more closely the cheese yields of different milks. This method is objectionable for the following reasons: (1) The poorest factory milk contains about 2 per cent of casein, while richer milks contain more (see Lecture 2, paragraph 5). By this method the richer milk does not get its full credit of casein and cheese yield. (2) This method is in favor of the poorer milk. (3) It makes no recognition of the fact that rich milk produces better quality of cheese than poor milk.

8. *Summary of reasons for using the milk fat basis in paying for milk at cheese factories*—

First. Because the amount of fat in milk offers the most accurate, practicable, and just basis we have for determining the cheese-producing value of milk.

Second. Because this method recognizes the fundamental truth that different milks possess different values for cheese making.

Third. Because this method, being based on truth, is just to all and is therefore in the highest sense businesslike.

Fourth. Because the adoption of this method results in an improvement in the quality of milk produced. It makes it pay to produce better milk.

Fifth. Because all temptation to adulterate milk by watering or skimming is removed, since a man receives pay for the number of pounds of fat he furnishes.

Sixth. Because improvement in the character of dairy animals will follow, and in consequence the yield and composition of milk, which means economy of production and increased profit.

9. *Method of making cheese-factory dividends on basis of milk fat.*—Several methods may be employed to determine the amount of each patron's dividend. Calculators are published, which save most of the details of figuring. We will present here the simplest methods, showing the necessary details. We want to calculate the dividends for one dividend period, whether a week or month. We must know four items: (1) The amount of milk delivered by each patron during the dividend period; (2) the per cent of fat in the milk for the same time; (3) total or gross amount of money received for the cheese produced during the same period, and (4) the expenses to be deducted from gross receipts, such as cost of manufacture, selling, carting, etc. Having these data, we need only to apply the following rule, which is stated, for convenience, in three steps:

Rule, step 1. To find the amount of milk fat furnished by each patron: Multiply together the per cent of fat in the milk and the

amount of milk delivered by each patron, expressed in hundreds of pounds and decimals of a hundred. This gives the total amount of fat in the milk delivered by each patron during the dividend period. The following table illustrates this calculation:

Illustration of method of calculating milk fat delivered by patrons.

Name of patron.	Pounds of milk delivered during dividend period by each patron.	Pounds of milk expressed in decimals of 100 pounds.	Percent of fat in milk during period.	Pounds of fat in milk delivered by each patron.
A.....	350	3.50	4.0	14.00
B.....	650	6.50	3.6	23.40
C.....	835	8.35	5.2	43.42
D.....	965	9.65	4.4	42.46
E.....	1,200	12.00	4.2	50.40
Total.....				173.68

Rule, step 2. To find the net value of 1 pound of milk fat: Divide the total net receipts by the total number of pounds of milk fat delivered by all the patrons during the dividend period. Example: From the amount of milk delivered by patrons, as previously given, there have been made, say, 452 pounds, which realizes 9 cents a pound after deducting all expenses. This will leave \$40.68 to distribute among the patrons. We now divide \$40.68 by 173.68, the total pounds of fat delivered by all patrons during the dividend period, and we have 23.42 cents as the net amount of money received from cheese for each pound of milk fat delivered.

Rule, step 3. To find the amount of dividend due each patron: Multiply together the number representing the pounds of milk fat furnished by each patron and the net price received for each pound of milk fat. In this case the net price received for each pound of milk fat is 23.42 cents, and we multiply by this the number of pounds of fat delivered by each patron. Example:

Name of patron.	Pounds of fat in milk delivered.	Net price received for each pound of fat.	Amount of money received by each patron.
A.....	14.00	\$0.2342	\$3.28
B.....	23.40	.2342	5.48
C.....	43.42	.2342	10.17
D.....	42.46	.2342	9.95
E.....	50.40	.2342	11.80

10. Examples for practice—

(1) A has 20 cows, which give each 30 pounds of milk a day, testing $4\frac{1}{2}$ per cent of fat. B has 30 cows, each giving 25 pounds of milk a day, testing $3\frac{1}{2}$ per cent of fat. (a) Which herd produces more milk fat per week, and how much? (b) If there is made daily from the milk of these

two herds 140 pounds of cheese, selling at 10 cents a pound net, what will be the dividend of each for thirty days on the basis of the weight of milk delivered by each? (c) What will be the monthly dividend of each on the milk-fat basis? (d) Does A gain or lose by milk-fat basis, and how much a month? (e) Does B gain or lose by weight of milk basis, and how much a month? (f) Calculate A's and B's daily gain or loss per cow for season of 180 days by each method of making dividends.

(2) A dairyman's herd produced during the factory season 18,000 pounds of milk, which contained 684 pounds of milk fat. (a) What was the average per cent of fat in the milk during the season? (b) How much ripened cheese did the milk produce, allowing 2.6 pounds of cheese for 1 pound of milk fat? (c) How much milk was required to make 1 pound of cheese? (d) How much cheese was made from 100 pounds of milk?

(3) Herd A with 10 cows produces during the factory season 36,000 pounds of milk, containing 3.6 per cent of fat. Herd B with 8 cows produces 30,000 pounds of milk, containing 4.5 per cent of fat. (a) Which herd produces more milk fat, and how much? (b) What will be the receipts of each herd on the milk-fat basis, assuming that each pound of milk fat nets 20 cents? (c) What would be the difference in the dividends of each, if payment were made on basis of weight of milk? (d) Assuming that the cost of keeping each cow is the same, which is the more profitable herd?

APPENDIX.

REFERENCES.

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3. Modern Dairy Science and Practice. Pennsylvania Department of Agriculture Bul. 104.
4. Investigation Made Relating to the Manufacture of Cheese during the Season of 1894. New York State Experiment Station Report 1894.
5. Relation of Fat in Milk to Yield of Cheese. New York State Experiment Station Report 1893.
6. Relation of Fat in Milk to Yield of Cheese. New York State Experiment Station Report 1892.
7. Fat in Milk as a Practical Basis for Determining the Value of Milk for Cheese Making. New York State Experiment Station Bul. 68.
8. Cheese Making, by John W. Decker. Columbus, Ohio, The Author, 1900.
9. Bacteria in Milk and its Products, by H. W. Conn. Philadelphia, Pa., P. Blakiston's Son & Co., 1903.
10. Relative Absorption of Odors in Warm and Cold Milk. Wisconsin Experiment Station Report 1898.
11. Outlines of Dairy Bacteriology, by H. L. Russell. Madison, Wis., The Author, 1905.
12. Testing Milk and its Products, by E. H. Farrington and F. W. Woll. Madison, Wis., The Authors, 1901.
13. Unorganized Ferments of Milk. Wisconsin Experiment Station Report 1897.
14. Properties of Galactase. Wisconsin Experiment Station Report 1898.
15. The Action of Proteolytic Ferments on Milk, with Special Reference to Galactase. Wisconsin Experiment Station Report 1899.
16. Conditions Affecting Chemical Changes in Cheese Ripening. New York State Experiment Station Bul. 236.
17. Conditions Affecting Weight Lost by Cheese in Curing. New York State Experiment Station Bul. 207.
18. The Cold Curing of Cheese. U. S. Department of Agriculture, Bureau of Animal Industry Bul. 49.
19. Experiments in Curing Cheese at Different Temperatures. New York State Experiment Station Bul. 234.
20. Construction of Cheese Curing Rooms. Wisconsin Experiment Station Bul. 70.
21. Chemical Changes in the Souring of Milk and their Relations to Cottage Cheese. New York State Experiment Station Bul. 245.

LIST OF BOOKS FOR CONSTANT USE.

- Cheese Making.** By John W. Decker. Published by the author, Columbus, Ohio, 1900.
- Bacteria in Milk and its Products.** By H. W. Conn, Ph. D. Published by P. Blakiston's Son & Co., Philadelphia, Pa., 1903.
- Handbook for Farmers and Dairymen.** By F. W. Woll, Ph. D. Published by John Wiley & Sons, New York City.
- Reports of New York State and Wisconsin Agricultural Experiment Stations from 1892 to date.** These are largely out of print, but are available for reference in libraries of agricultural colleges and experiment stations.
- Dairy Chemistry.** By Henry Droop Richmond. Published by J. B. Lippincott & Co., Philadelphia, Pa., 1900. This work is recommended where one has some knowledge of chemistry and desires to go deeply into the subject of dairy chemistry.

LIST OF APPARATUS AND MATERIALS NEEDED.

[Prices are retail catalogue prices, subject to some discount.]

1 cheese vat, self-heating, 100 gallons, divided into four equal compartments.....	\$50.00
1 standing cheese press, 4 screws $1\frac{1}{2}$ by 20 inches high.....	35.00
Galvanized steel cheese hoops for standing press—	
4 Young America, 7 by 9 inches, at \$2.....	8.00
4 Young America, 12 by 8 inches, at \$2.15.....	8.60
2 Young America, $14\frac{1}{2}$ by 10 inches, at \$2.80.....	5.60
6 fibrous press rings for 12 by 8 inch hoops, at \$0.35.....	2.10
6 fibrous press rings for $14\frac{1}{2}$ by 10 inch hoops, at \$0.35.....	2.10
6 fibrous press rings for 7 by 9 inch hoops, at \$0.25.....	1.50
1 bandage for Young America hoop.....	.50
1 bandage for 12 by 8 inches.....	.75
1 bandage for $14\frac{1}{2}$ by 10 inches.....	.75
100 cheese bandages, 7 by 9 inches.....	1.00
100 cheese bandages, 12 by 8 inches.....	1.35
100 cheese bandages, $14\frac{1}{2}$ by 10 inches.....	1.80
1 pair curd knives, 8 by 22 inches perpendicular and 6 by 22 inches horizontal ...	4.20
1 special 240-pound combination scale.....	2.50
1 flat side curd pail.....	1.00
1 curd scoop.....	.65
1 gallon dipper.....	.65
1 whey siphon with gate and valve.....	2.00
1 whey strainer.....	.80
3 new standard large bulb-floating, dairy-guaranteed correct thermometers, at \$0.50	1.50
1 vat scrub brush.....	.25
1 cheese trier, 6 by $\frac{3}{4}$ inches.....	.90
4 ounces cheese color.....	.25
1 gallon rennet extract.....	1.60
Or 50 rennet tablets.....	2.20
Babcock tester traveling outfit, 4-bottle size (or larger).....	10.00
12 test bottles, for whole milk.....	4.20
12 test bottles, double bore skim milk and whey.....	5.00
6 test bottles, for cream or cheese.....	1.00
1 gallon sulphuric acid of proper strength.....	.70
1 Farrington's alkaline acid tests for milk, whey, etc.....	2.75 and 4.75
1 Mann's acid test.....	4.75

1 testing scale for weighing solids with metric weights.....	\$2.00
1 milk sampler.....	1.00
1 Marshall rennet test.....	2.50
1 Monrad rennet test.....	1.00
1 graduate, 8-ounce.....	.30
1 hygrometer for determining moisture.....	1.50
1 10-inch hair sieve.....	.60
3 1-cubic-centimeter pipettes, at 10 cents.....	.30
3 10-cubic-centimeter pipettes, divided into tenths, at 20 cents.....	.60
1 milk-bottle tester (brass plunger).....	.75
2 Quevenne lactometers.....	1.00
1 New York State Board of Health lacto-thermometer.....	1.50
1 test jar for lactometer, 11 by 2.....	.30
6 Petri dishes, at 30 cents.....	1.80
24 test tubes, 5 inches by $\frac{1}{8}$ inch, at 30 cents per dozen.....	.60

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON FARMERS' INSTITUTES.

BULLETINS.

- Bulletin No. 79.—Farmers' Institutes: History and Status in the United States and Canada. By H. L. Bailey. Pp. 34. 1900.
- Bulletin No. 119. Proceedings of the Sixth Annual Meeting of the American Association of Farmers' Institute Workers, held at Buffalo, N. Y., September 18 and 19, 1901. Edited by A. C. True, D. J. Crosby, and G. C. Creelman. Pp. 55.
- Bulletin No. 120. Proceedings of the Seventh Annual Meeting of the American Association of Farmers' Institute Workers, held at Washington, D. C., June 24-26, 1902. Edited by A. C. True and D. J. Crosby for the Office of Experiment Stations, and G. C. Creelman for the Association. Pp. 119.
- Bulletin No. 135 (Revised). Legislation Relating to Farmers' Institutes in the United States. By John Hamilton, Farmers' Institute Specialist. Pp. 53. 1903.
- Bulletin No. 138. Proceedings of the Eighth Annual Meeting of the American Association of Farmers' Institute Workers, held at Toronto, Ontario, June 23-26, 1903. Edited by W. H. Beal for the Office of Experiment Stations, and G. C. Creelman for the Association. Pp. 119.
- Bulletin No. 154. Proceedings of the Ninth Annual Meeting of the American Association of Farmers' Institute Workers, held at St. Louis, Mo., October 18-20, 1904. Edited by W. H. Beal and John Hamilton for the Office of Experiment Stations, and G. C. Creelman for the Association. Pp. 91.
- Bulletin No. 155. Agricultural Instruction for Adults in the British Empire. By John Hamilton. Pp. 96. 1905.
- Bulletin No. 163. Agricultural Instruction for Adults in Continental Countries. By John Hamilton. Pp. 32. 1905.
- Bulletin No. 165. Proceedings of the Tenth Annual Meeting of the American Association of Farmers' Institute Workers, held at Washington, D. C., November 9-11, 1905. Edited by W. H. Beal and John Hamilton for the Office of Experiment Stations, and G. C. Creelman for the Association. Pp. 95.

CIRCULAR.

- Circular No. 51 (Revised). List of State Directors of Farmers' Institutes and Institute Lecturers of the United States. By John Hamilton. Pp. 32. 1905.

SEPARATES.

- Farmers' Institutes in the United States. By D. J. Crosby. Reprint from Annual Report of the Office of Experiment Stations for the year ended June 30, 1902. Pp. 25.
- Farmers' Institutes in the United States. By John Hamilton. Reprint from Annual Report of the Office of Experiment Stations for the year ended June 30, 1903. Pp. 57.
- Farmers' Institutes. By John Hamilton. Reprint from Yearbook, Department of Agriculture, 1903. Pp. 10.
- Annual Report of Farmers' Institutes. By John Hamilton. Reprint from Annual Report of the Office of Experiment Stations for the year ended June 30, 1904. Pp. 53.
- Farmers' Institutes in the United States. By John Hamilton. Doc. No. 711. Pp. 20. A pamphlet prepared for distribution at the Louisiana Purchase Exposition.

LECTURES.

- Farmers' Institute Lecture No. 1. Syllabus of Illustrated Lecture on the Care of Milk, accompanied with 44 lantern slides. By R. A. Pearson. Pp. 12. 1904.
- Farmers' Institute Lecture No. 2. Syllabus of Illustrated Lecture on Potato Diseases and their Treatment, accompanied with 47 lantern slides. By F. C. Stewart and H. J. Eustace. Pp. 30. 1904.
- Farmers' Institute Lecture No. 3. Syllabus of Illustrated Lecture on Acid Soils, accompanied with 31 lantern slides. By H. J. Wheeler. Pp. 28. 1904.
- Farmers' Institute Lecture No. 4. Syllabus of Illustrated Lecture on Profitable Cattle Feeding, accompanied with 45 lantern slides. By F. B. Mumford. Pp. 21. 1905.
- Farmers' Institute Lecture No. 5. Syllabus of Illustrated Lecture on Silage and Silo Construction for the South, accompanied with 50 lantern slides. By A. M. Soule. Pp. 31. 1905.
- Farmers' Institute Lecture No. 6. Syllabus of Illustrated Lecture on Essentials of Successful Field Experimentation, accompanied with 32 lantern slides. By C. E. Thorne. Pp. 24. 1905.

